DEPARTMENT OF THE INTERIOR
HUBERT WORK, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

BULLETIN 752

COAL RESOURCES OF THE RATON COAL FIELD, COLFAX COUNTY NEW MEXICO

BY

WILLIS T. LEE

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COAL RESOURCES OF THE RATON COAL FIELD, COLFAX COUNTY, NEW MEXICO.

By Willis T. Lee.

PURPOSE OF THE REPORT.

The purpose of this report is to present an account of the general geologic features and the coal resources of the developed part of the Raton coal field of New Mexico. This is a small part of the area of coal-bearing rocks in Colorado and New Mexico known as the Raton Mesa region, which extends about 90 miles from north to south and 50 miles or more from east to west and which includes the Trinidad coal field of Colorado and the Raton coal field of New Mexico. The medium rank of bituminous coal which occurs throughout this region compares favorably in quality with the best bituminous coal of Ohio and other parts of the United States. Much of the coal will coke, and in many places it occurs in thick beds that are easily mined. The quantity, quality, and accessibility of the coal renders this one of the most important coal-producing regions in western America, as is indicated by the fact that during the 10 years from 1911 to 1920 it yielded more than 27,330,000 tons of coal. During the same period the production of the Raton field increased from 2,297,611 tons in 1911 to 3,114,604 tons in 1917.

The area described in this paper forms a small part of the Raton coal field, though it includes most of the developed portion. It is shown on the maps of the Raton, Brilliant, and Koehler quadrangles, published by the United States Geological Survey, and on the map of the Dawson area presented in Plate XIII (p. 120). Coal has been mined on a commercial scale near Raton ever since the early seventies. The first large mines, which were near Blossburg, were operated for many years but finally abandoned, for coal could be mined to better advantage at Koehler, Van Houten, and Dawson. The mines most recently developed are at Brilliant, Gardiner, Sugarite, and Swastika.

Though the coals of the Raton Mesa region are among the most valuable in the West, their quality varies greatly from place to place, particularly in the part of the Raton field described in this bulletin. The coal beds are here relatively thick, contain an excellent quality of coal, lie almost horizontal, and are not faulted or

warped to any notable extent. But the best beds do not occur in all places, and at some localities where they do occur the coal has been destroyed by intrusion of igneous rock.

The most valuable beds of coal occur in rocks that were uplifted after the coal beds had been formed and cut away in some places during a period of erosion that followed. On the eroded surface thus formed the younger coal-bearing rocks were laid down, as explained in detail on page 12. This removal of the older coal beds from part of the field renders necessary very careful preliminary work in order to ascertain where the valuable bodies of coal occur on which mines may be opened. In some places in the mines the coal was reduced in thickness, presumably by this erosion, to such an extent that it can not be mined with profit under present conditions. This will be described in detail later in the paper.

Scarcely less serious, from the miner's standpoint, is the destruction of the coal in some places by the intrusion of igneous rock that coked the coal or burned it out completely. Where the intrusion took the form of dikes the coal was affected only locally. But in many places the igneous rock was forced either into the coal bed or so near it that the coal was coked. Where this has occurred the coal bed is almost valueless, for it has been found that the cost of removing such bodies of coal as escaped destruction is so great that they can not be recovered with profit.

The value of the coal beds of the younger formation is affected in another but scarcely less serious manner. They are much less regular in thickness than the older beds originally were and are much more irregular in physical character, consisting of complex series of coal, bone, and shale layers. It is well known that coal beds are broad lenses thinning out and finally disappearing laterally. The younger coal beds of this field are more than ordinarily lenticular. Some of them seem to be continuous for considerable distances, others to thin and disappear within short distances, as illustrated in Plate XII (p. 78), where it appears that certain beds penetrated by the drill at one locality are not present at neighboring localities. These younger beds consist of many layers of coal separated by shale. The layers of coal and of shale differ in thickness from place to place so that a bed which contains a valuable body of coal at one locality may be so shaly as to be commercially worthless at a neighboring locality. In prospecting these higher beds the problem is not to ascertain the continuity of the bed, as it is with the lower coals, but to find localities where the coal is thick enough, clean enough, and of sufficient extent to be mined with profit.

Although the Raton field contains a large quantity of valuable coal in beds of great commercial value, it is a field where careful prospecting is necessary before a mine can be intelligently located

and where each unit of area must be judged on its own merits. For this reason the writer has refrained from making the customary estimates of tonnage for the area described. Much more prospecting must be done before an estimate of tonnage for the entire field can be made that will be of much value. This paper consists very largely of descriptive details that confirm these general statements.

The coal beds are described in order of their age, beginning with the oldest. As the evidence of geologic age of the coal-bearing rocks has been presented in detail in previous publications[1] this subject is here touched lightly. However, the effect of structure on the occurrence of the coal beds is of great economic importance and this is described in detail. Also the attitude of the coal beds and the relation of their outcrop to mesa slopes, canyons, and other features is described in connection with the approach to the coal beds of lines of transportation, and finally the quality of the coal and the methods employed in mining it are described.

METHODS OF WORK.

The methods by which the coal beds of the Raton coal field were studied differ somewhat from those employed in other fields, and a brief explanation may help in understanding certain parts of the report. The lowest coal bed of this field, commonly known as the Raton coal, occurs in what is now known as the Vermejo formation. It was first opened near the town of Raton, from which it is known as the Raton coal. Later when the coal-bearing rocks were separated into two formations, the younger one was named Raton. This formation contains many beds of coal, but the Raton coal is not one of them, and the name Raton formation must not be confused with the name Raton coal bed. The Raton coal bed is well exposed in many places and has been carefully surveyed and prospected wherever it outcrops in the area described. It has also been penetrated in many places by the diamond drill. The information thus obtained, together with that derived from the mine maps and reports, has been utilized to supplement the observations made by the writer and his assistants.

With the higher beds, however, it is quite different. Mines have been opened on them in only a few places and relatively small parts of their outcrop have been systematically prospected. In few places can these upper beds be followed continuously at the outcrop for any considerable distance because of poor exposures, and indeed in many places no surface indication of their presence was found. However, in the canyons and on some of the prominent ridges fairly

[1] Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, 1918.
Lee, W. T., U. S. Geol. Survey Geol. Atlas, Raton-Brilliant-Koehler folio (No. 214), 1922.

good vertical sections were measured. In these sections the altitude of a given bed above some recognizable horizon, such as the top of the Trinidad sandstone, was determined by Locke level, and the sections together with the drill records give the best means available in most places for judging of the continuity or lack of it of the several beds of coal.

The mine entries and some of the old prospect openings were located when the contour map was made but without reference to their relation to the land corners as they are marked on the ground. Later the land net was superimposed on the topography of the map with actual knowledge of the position of only a few of these corners. Hence, the land net shown in the eastern part of the map of the Raton quadrangle indicates only approximate positions with reference to legal subdivisions.

Many of the prospect openings in which detailed measurements of the coal beds were made several years ago can not now be identified, and therefore their location can be shown only approximately on the accompanying map (Pl. I, in pocket). However, most of them are so described that this approximate location is regarded as sufficiently accurate for all practical purposes.

ACKNOWLEDGMENTS.

The writer's study of the Raton coal field dates back nearly to 1900 and has continued intermittently until the present time, chiefly under the general supervision of M. R. Campbell. The first detailed work on the coal resources was done during the summer of 1907 when the writer was assisted by A. L. Beekly and C. S. Blair. At that time the unconformity that separates the coal-bearing rocks into two formations was discovered. Two years later, assisted by J. B. Mertie, he spent the summer making a comprehensive study of the stratigraphic relations of the coal-bearing rocks to neighboring formations. The results of this work were published by the U. S. Geological Survey in Professional Paper 101 and in Geologic Folio 214. In 1910 the topographic survey of the Raton field was begun on a scale that would furnish an adequate base for mapping the rock formations and for showing the location of the coal beds, but not until the summer of 1913 did the writer have the opportunity of continuing his study of this area. Then, with the assistance of K. C. Heald, he completed the main part of the work that has resulted in the present bulletin. The intense activity in the coal mining industry during the next five years resulted in the accumulation of much new information concerning the coal resources of the Raton field. During the summer of 1919 the writer spent six weeks in this field gathering new information for the purpose of bringing the report up to date. As the body of the report

was written in 1914 some of the conditions that are described no longer exist. However, in general the descriptions have been revised so that they express the conditions that existed in the summer of 1919.

A large amount of information has been furnished for this report by the mining companies of the Raton field. The principal mines here described are owned and operated by the St. Louis, Rocky Mountain & Pacific Co. and the Phelps-Dodge Corporation. The president of the former company, Mr. J. Van Houten, has furnished for this report all the available information regarding the six large producing mines owned by his company, the preliminary surveys and records of prospect openings made preparatory to opening these mines, and the records of the several diamond-drill prospects. A large part of the exact information contained in this report was derived from the records thus placed at the writer's disposal, and it is a pleasure to give hearty acknowledgment for this generous cooperation. Equally hearty cooperation was given by the officials of the Phelps-Dodge Corporation at Dawson, N. Mex., who furnished all available maps and records of the Dawson mine. The writer wishes also to acknowledge his indebtedness to the late Orestes St. John, for many years the geologist of the St. Louis, Rocky Mountain & Pacific Co., and to the engineers, especially Frank Young, John Corruthers, and David Thompson; also to the several mine superintendents who took great pains in giving him every opportunity possible for investigation. Valuable information was furnished also by the New Mexico-Colorado Coal & Mining Co., locally called the Yankee Fuel Co., whose mines are at Yankee, N. Mex., including maps, drill records, and graphic sections of mine measurements made by the general superintendent of the company, H. L. Handley. The Yankee mines, however, were not in operation in 1919.

GEOGRAPHY.

Location of the field.—The area described in this bulletin includes all the coal land of the Raton field east of the town of Raton. Toward the west the coal beds underlie the highlands that occupy the central part of the Raton Mesa region. The area extends from the northern boundary of New Mexico southward beyond Dawson, a distance of about 40 miles. The trunk line of the Atchison, Topeka & Santa Fe Railway passes through it, and it has an outlet to the Colorado & Southern Railroad through a branch line of the Santa Fe known as the St. Louis, Rocky Mountain & Pacific Railway. The El Paso & Southwestern road reaches it by a branch that extends from the main line at Tucumcari, N. Mex., to Dawson, which is a few miles south of the area mapped. The relation of this area to the Raton Mesa region and to the lines of transportation is shown on the index map, Figure 1.

Surface features.—The surface features that have an intimate relation to the development of the coal beds are the only ones described here. Among the most conspicuous of these are the high mesas of the Raton quadrangle in the eastern part of the area. These mesas have sometimes been erroneously called mountains and they are described in the older writings as the "Raton Mountains."

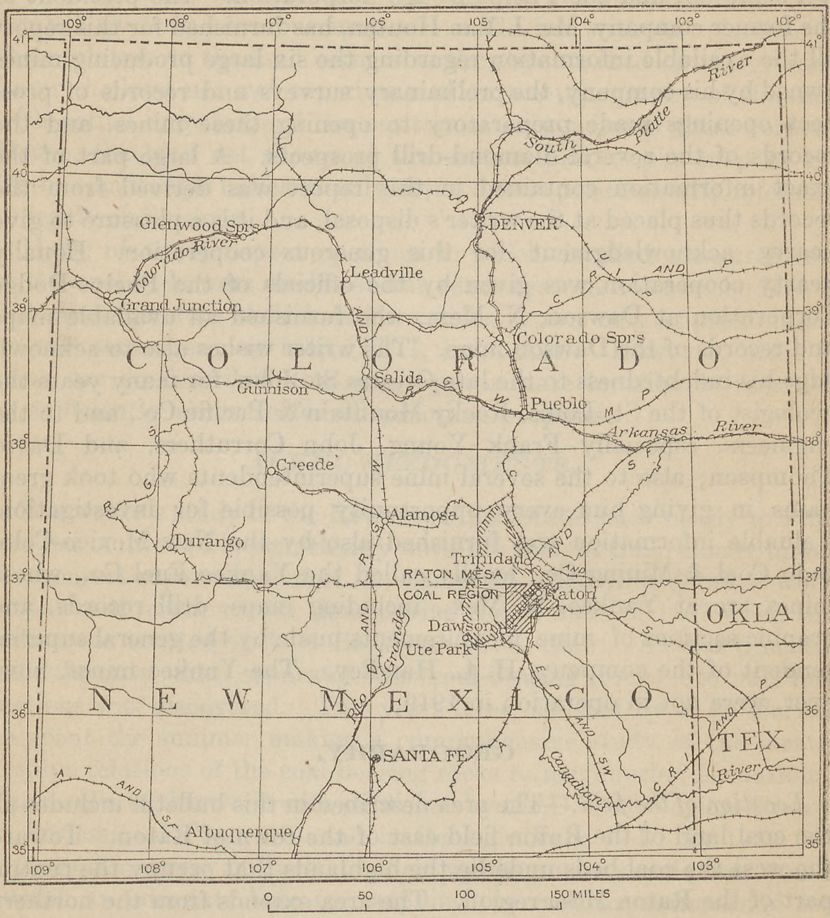


FIGURE 1.—Index map showing the relation of the Raton coal field to neighboring regions. The Raton Mesa coal region, including the Raton field in New Mexico and the Trinidad coal field in Colorado, is outlined in light shading and the part of the Raton field described in this report in dark shading.

However, because of their obvious table-land or mesa character and because of the equally obvious inappropriateness of calling them mountains, the term Raton Mesa region has been adopted by the United States Geological Survey for the coal-bearing area of Colorado and New Mexico that includes the Trinidad and Raton fields. These mesas rise to altitudes ranging from 8,000 to 9,500 feet, or 1,500 to 3,500 feet above the level of the surrounding plain. (See fig. 2.)

They contain coal beds which outcrop in their sides and in the walls of the canyons that have been eroded in them. The highlands in the Brilliant and Koehler quadrangles consist of narrow ridges separated by deep valleys. Because of the absence of the hard protecting layers of rock that have preserved the surface of the mesas, the coal-bearing rocks of this part of the area are deeply cut by many branching canyons in the sides of which the coal beds crop out. These features are of great advantage in mining. The mine openings are so located that the coal is brought to the surface at tipple height above the bottoms of the canyons, so that it descends through the screens directly to the railroads that are built in the bottoms of the canyons. This relation is illustrated in Plate XVII, *B* (p. 152), which shows the tramways on both sides of the canyon descending to the tipple, beneath which the cars are loaded for shipment.

Although the drainage system in the Raton field is well developed, there are few permanent streams. The run-off results mainly from the torrential showers, popularly known as "cloudbursts," which occur frequently on or near the mesas and cause destructive floods of short duration. Usually a little water flows in Crow Creek, Canadian River, Dillon Creek, and Sugarite Creek, but most of the other streams are intermittent, and the problem of procuring water for mining operations is a serious one.

Although precipitation is insufficient to maintain permanent streams, it is sufficient to cause a dense growth of brush, especially near the tops of the mesas. In many places this brush so completely obscures the surface that no undisturbed rock is exposed for long distances and the ex-

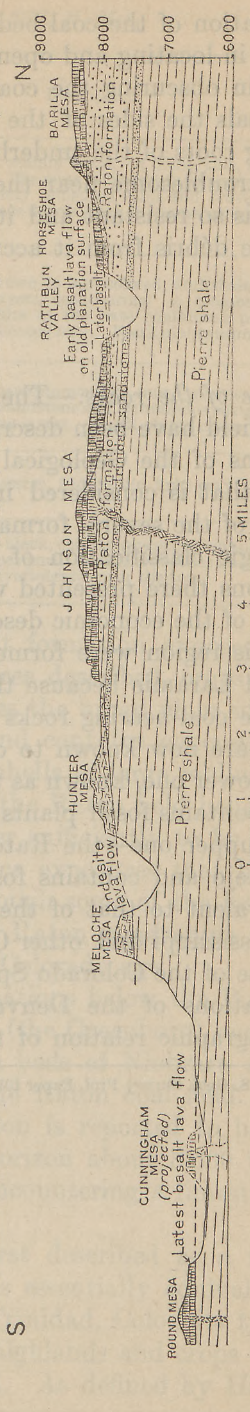


FIGURE 2.—Profile section in the eastern part of the Raton coal field from Round Mesa through Johnson and Barilla mesas, showing the relations of the eroded plain to the mesas and of the sedimentary rocks to the caps of lava.

amination of the coal beds is thus made impossible without extensive work in locating and opening the beds. Another surface feature that aids in obscuring the coal beds is the covering of rock débris which conceals the sides of the mesas and is held together by the interlacing roots of the underbrush. This débris is especially abundant and troublesome near the tops of the mesas. The basalt of the cap rock is so resistant and its disintegration so slow that large masses of the débris from it accumulate on the surface.

GEOLOGY.

STRATIGRAPHY.

Age of the rocks.—The stratigraphy and structure of the Raton coal field have been described in detail by the writer in recent publications of the Geological Survey.[2] These publications describe the area that is considered in this bulletin and give in detail the relations of the several formations to each other and the reasons for the geologic classification of the rocks. A brief summary of the conclusions there presented will therefore be sufficient here to form the basis of the economic descriptions to follow. The coal-bearing rocks of this region were formerly all included in a single formation and called Laramie because they were supposed to be equivalent in age to the coal-bearing rocks called Laramie in fields farther north, but they are now known to consist of two distinct geologic formations. The lower one, known as the Vermejo formation, is of Cretaceous age and contains fossil plants that indicate that it is older than Laramie. The upper one—the Raton formation—rests unconformably on the Vermejo and contains fossil plants that indicate essentially an age equivalent to that of the older Eocene (Tertiary) formations found in Mississippi and other Gulf States and also to that of the Dawson arkose of the Colorado Springs region and the Denver and Arapahoe formations of the Denver Basin. The following table shows the stratigraphic relation of the formations exposed in the Raton field:

[2] U. S. Geol. Survey Prof. Paper 101, 1918; Geol. Atlas, Raton-Brilliant-Koehler folio (No. 214), 1923.

Geologic formations exposed in the Raton coal field, N. Mex.

System.	Series.	Group and formation.		Thickness (feet).	Description.
Quaternary.	(?)	(?)		200±	Igneous rock, mainly basalt, in dikes, sills, stocks, and flows. The mesa lavas rest in some places on beds of loosely cemented sand and gravel that formed surface débris when the lavas were poured out.
Tertiary.	Eocene.	Raton formation.		1,150	Sandstone, brown to buff-colored, and shale in alternating layers; coal-bearing. A conglomerate usually occurs at the base containing pebbles mainly of siliceous rock. Fossil plants numerous.
		Unconformity.			
Cretaceous.	Upper Cretaceous.	Montana group.	Vermejo formation.	0-200±	Dark shale, carbonaceous in many places, light-gray friable sandstone and bituminous coking coal in alternating layers. Fossil plants numerous.
			Trinidad sandstone.	100	Sandstone, massive, feldspathic, light gray.
			Pierre shale.	3,000±	Shale, drab to black, containing concretions of limestone in upper part. Bones of reptiles and shells of marine invertebrates near the top.

Pierre shale.—The Pierre shale, the oldest formation exposed in the vicinity of Raton, underlies the whole area described, crops out in the lower slopes of the mesas, and occupies the broad plain south of Raton. The shale is of marine origin and contains concretions of limestone, many of which are full of the shells of large mollusks. Cretaceous rocks older than Pierre occur in the Raton field beneath this shale, but they do not differ in character sufficiently to be distinguished in well borings nor in the surface exposures that have yet been found to the east of the field, although some of the fossils collected from the southeastern part of the Raton quadrangle and from the eastern part of the Koehler are of Colorado age.

In southern Colorado the Cretaceous formations below the Pierre are well defined, and a prominent limestone (the Greenhorn) occurs in the strata of Benton age and another in beds of Niobrara age. But these formations do not crop out in the Raton coal field. A well drilled about 2 miles northeast of Raton is reported to have reached a depth of about 2,700 feet or a horizon about 3,000 feet below the top of the Pierre shale without encountering a limestone formation.

Trinidad sandstone.—The Trinidad was first described as a formation by R. C. Hills [3] and was regarded as essentially equivalent in age to the Fox Hills sandstone. From Trinidad, Colo., its type locality, it extends southward beneath the highlands and crops out in the sides of the mesas in the Raton field. As defined by Hills,

[3] Hills, R. C., U. S. Geol. Survey Geol. Atlas, Elmoro folio (No. 58), 1899.

the Trinidad formation consists of a sandstone 70 to 80 feet thick—called by him Upper Trinidad—and a series of thin layers of sandstone and shale about 75 feet thick called Lower Trinidad. Later usage has restricted the name Trinidad to the sandstone or Upper Trinidad of Hills, and his Lower Trinidad has been included in the underlying Pierre shale. Hence the Trinidad sandstone of this report is the cliff-making sandstone approximately 100 feet thick that separates the Pierre shale from the coal-bearing rocks (Vermejo formation).

Like the Pierre shale, the Trinidad is mainly of marine origin and contains impressions of shells of marine mollusks and great numbers of fossil seaweed (*Halymenites major*). In some of the older reports this sandstone is called the "*Halymenites* sandstone." These fossil seaweeds can usually be found wherever the sandstone is exposed and are often useful to the prospector in identifying the rocks, for nowhere within the Raton Mesa region does coal occur below this sandstone. Throughout this region the most valuable beds of coal lie either on the Trinidad sandstone or a few feet above it.

The Trinidad is a massive light-colored feldspathic sandstone without notable partings of shale. In most places it is harder than the rocks immediately above or below it, except where the basal conglomerate of the Raton formation rests upon it, so that it stands out as a prominent cliff in the sides of the mesas. (See Pl. X, *A*, *B*, p. 78.)

The Trinidad sandstone apparently was formed near the shore of the Cretaceous sea and represents the change from marine conditions, when sea water occupied this part of the Cretaceous Basin, to the nonmarine or swampy conditions favorable for the accumulation of coal. This sandstone is utilized to some extent as a building stone, and several of the buildings in Raton and in other towns of this field are constructed of stone quarried near by. Also some of the coke ovens and mine buildings are made of it. However, the sandstone weathers too easily to be very useful as building material. When exposed to the weather it gradually disintegrates and crumbles.

Vermejo formation.—The name Vermejo was proposed by the present writer for the coal-bearing rocks that lie between the Trinidad sandstone and the Raton formation, which is described below. The classification of these rocks as a separate formation was the result of the work described in Professional Paper 101, but owing to delay in publication the name was used elsewhere[4] before that paper appeared. The Vermejo formation consists of coal-bearing sandstone and shale, principally of fresh water origin. The type locality of the formation is in Vermejo Park, several miles west of Raton, where it has a maximum thickness of about 375 feet and is coal bearing throughout. It

[4] Lee, W. T., Recent discovery of dinosaurs in the Tertiary: Am. Jour. Sci., 4th ser., vol. 35, p. 531, 1913.

rests conformably on the Trinidad sandstone, and although the change from this sandstone to the coal-bearing rocks is abrupt in the Raton field, there is no evidence that this change indicates a time break between them. In other parts of the region the transition is not so abrupt, and there is reason to believe that sedimentation was continuous from Trinidad sandstone to Vermejo. The formation thins toward the east and is absent in some places. It does not occur at the outcrop for a considerable distance between Koehler and Van Houten and is absent in the vicinity of Red River Peak. Northeast of Raton it thins out, and it appears in outcrops farther east only as thin isolated remnants that escaped erosion and now occur in some places between the basal conglomerate of the Raton formation and the underlying Trinidad sandstone.

In the area described in this bulletin the Vermejo consists mainly of shale and coking bituminous coal. In some places it contains three well-defined beds of coal, in others two or only one, and in still other places no coal has been found. This variation from place to place in the number of coal beds has been interpreted by some geologists and mining engineers as due to lenticularity of the coal beds. More detailed work than has yet been done is needed in order to state what proportion of the variability is due to lateral thickening and thinning or to coalescence of the coal beds, but certain considerations render another explanation probable.

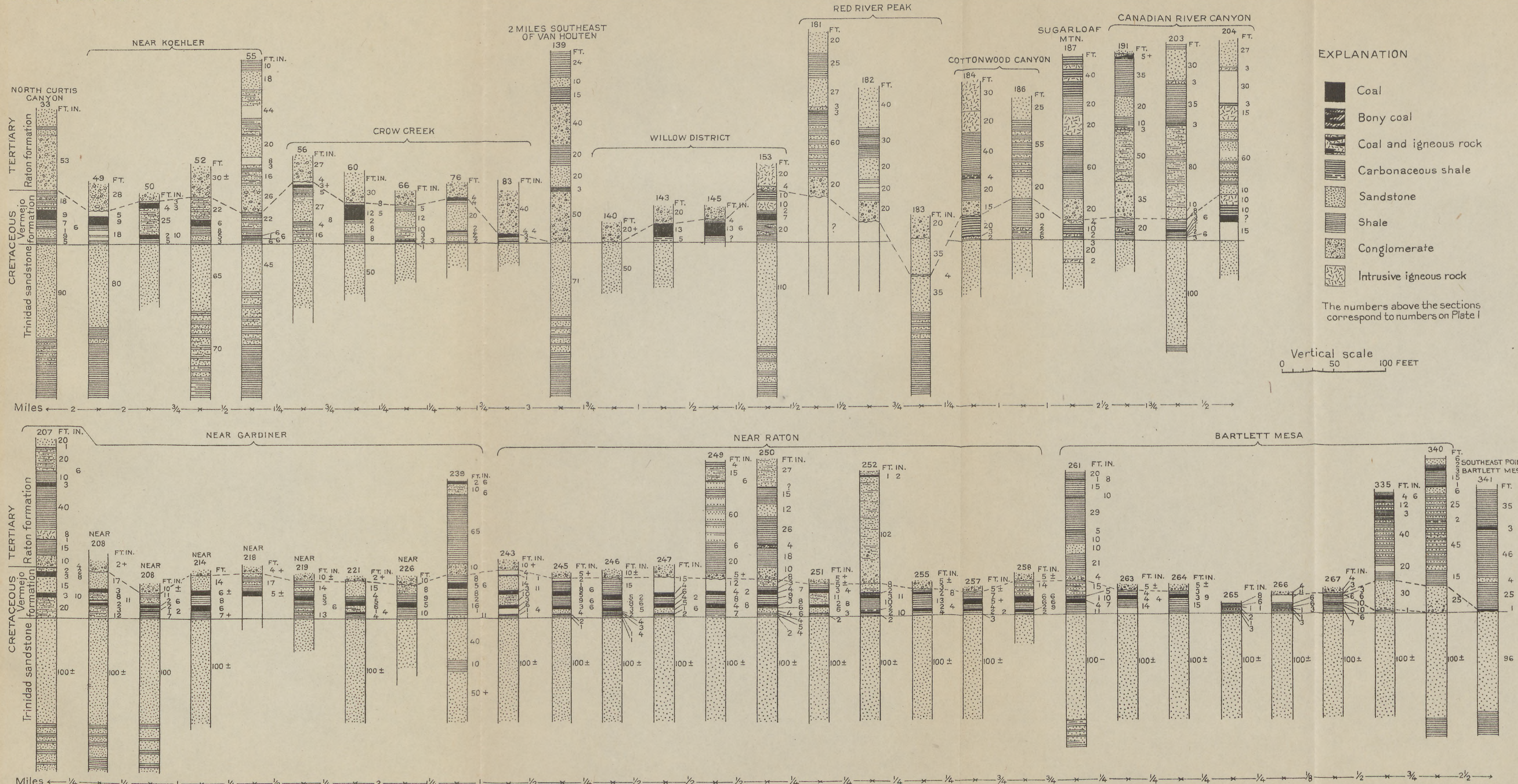
There are good reasons for believing that the Vermejo coals were formed in swamps lying but little above sea level and that a bed of coal represents a surface that was nearly level during the time that the vegetable matter from which the coal was formed was accumulating. Under such circumstances extreme lenticularity of the coal beds seems improbable, and where columnar sections measured close together differ notably in thickness and in the number of coal beds the differences may indicate a period of erosion which removed some of the Vermejo beds. This is illustrated in Plate II, and many details of this relation will be presented in connection with the descriptions of the coal for the several localities.

The Vermejo formation occurs in all parts of the Raton Mesa region except where it has been removed by erosion, and fossils, consisting mainly of plants, have been collected from it in many places. Most of the fossils are impressions of leaves that occur in the shale which overlies the coal and were collected near the mines. They indicate, according to F. H. Knowlton, who has studied them in detail, that the Vermejo formation is of Montana age and is somewhat older than Laramie. The details on which determination of age rest have been published by Knowlton in the second part of Professional Paper 101.

Evidence of the removal of parts of the Vermejo formation during the post-Cretaceous period of erosion was found at many of the localities described later in this bulletin. In some places well-marked angularity was noted between the planes of bedding of the Vermejo and those of the overlying Raton formation, and in others the absence of the Vermejo is best explained on the basis of its removal by erosion. At many of the localities examined in detail the evidence of erosion at the top of the Vermejo is unmistakable. Certain easily recognizable beds, such as coal, where traced laterally, disappear abruptly at the line of separation between the Vermejo and the overlying formation in a manner clearly indicative of erosion. The evidence of an erosion interval following the deposition of the Vermejo is substantiated in several ways, as described in Professional Paper 101.

Raton formation.—The coal-bearing rocks that lie unconformably on the Vermejo formation constitute the Raton formation. The name was proposed by the writer, and like that of the Vermejo, was introduced into geologic literature in 1913. The Raton formation includes the upper part of the beds that were formerly called Laramie in this region. It is about 1,150 feet thick near Raton and consists of sandstone and shale in which coal beds occur at several horizons. These coal beds occur in two general groups—one near the base, in which the coal beds are only locally of commercial importance, and the other in the upper part, in which there are several thick beds of coal.

The base of the Raton formation in nearly all parts of the Raton Mesa region is conglomeratic, but in the Raton quadrangle, the pebble beds occur only locally. In the southern part of the Brilliant quadrangle and the northern part of the Koehler, the pebble beds are massive and prominent, but near Dawson they are inconspicuous. Near Koehler (Pl. III, *A*) and in the several tributaries of Crow Canyon (Pl. V, p. 32) the conglomerate has a maximum thickness of 50 feet or more and forms well defined cliffs that are readily recognizable in the walls of the canyons. Near Van Houten also it is present (Pl. VII, *A*, p. 48) but is thinner than it is farther south and the pebbles contained in it are smaller. It is distinctly recognizable in Canadian River canyon, but the pebbles are few and small. Farther to the northeast, between Blossburg and Linwood Canyon, east of Raton, very few pebbles were found in it and some difficulty was experienced in tracing it. However, where the conglomeratic character disappears, the basal sandstone takes on a quartzose character and differs in appearance from neighboring sandstones. Near the mouth of Linwood Canyon it is locally conglomeratic, but farther east the conglomerate is absent in some places, as near the mouth of Sugarite Canyon, and the overlying shale rests on the Trinidad sand-

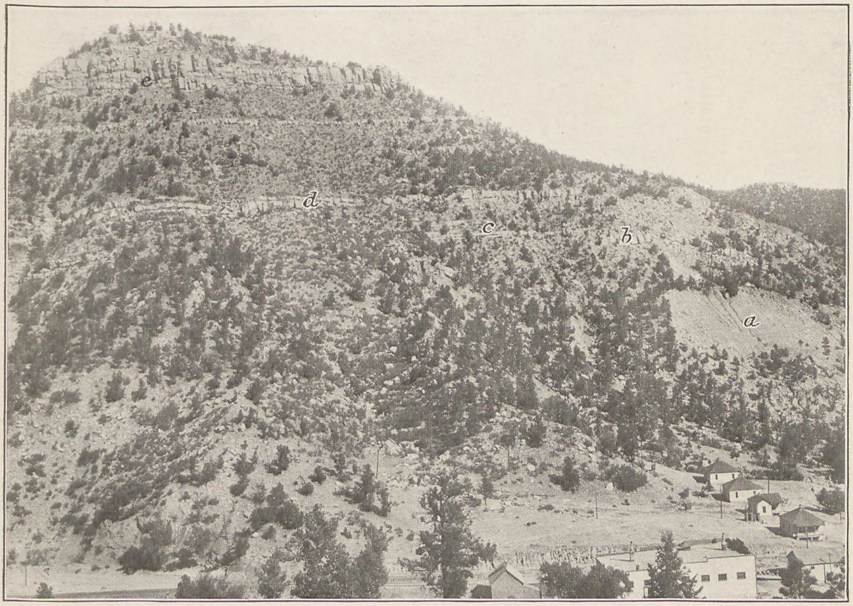


SECTIONS MEASURED AT THE OUTCROP OF THE RATON COAL BED BETWEEN KOEHLER AND SUGARITE, N. MEX.

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

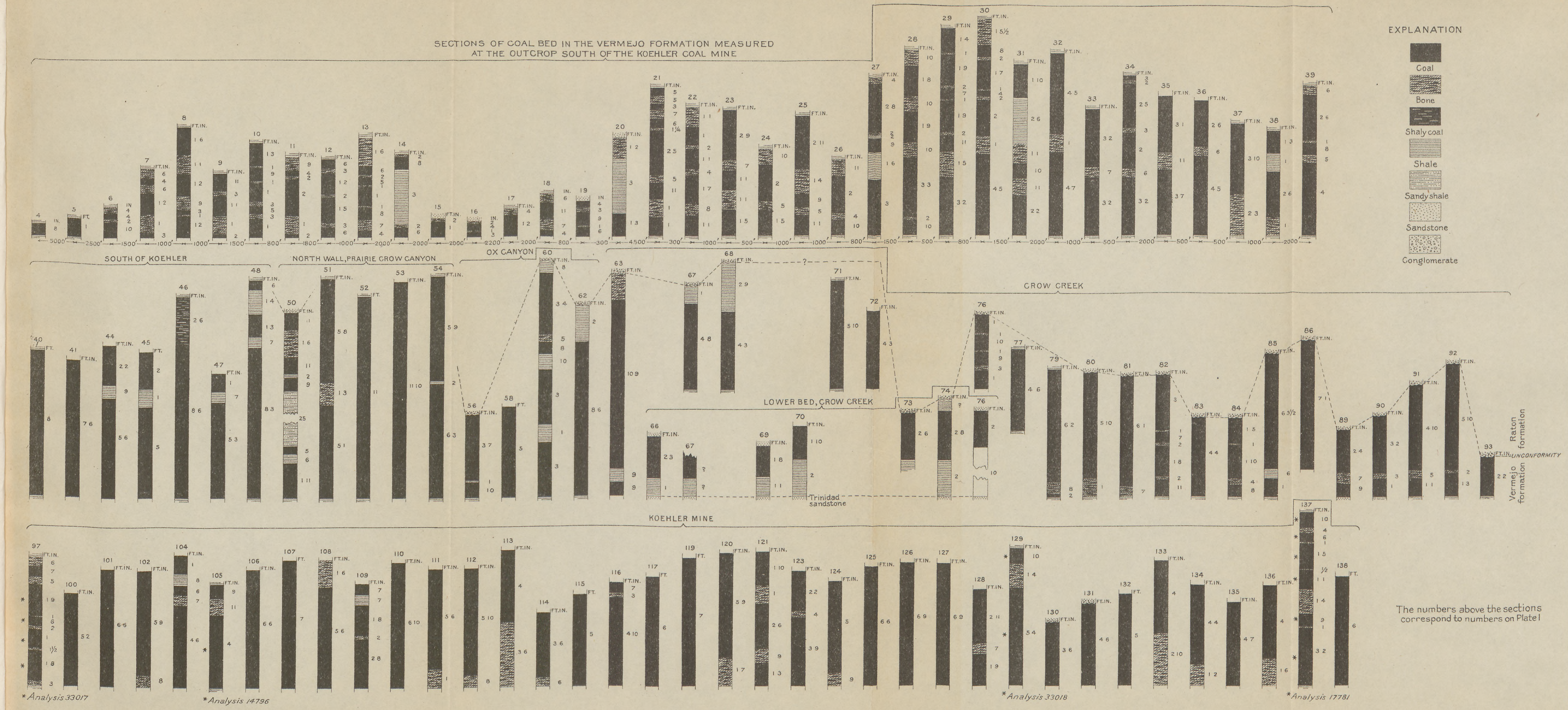
A. NORTH WALL OF PRAIRIE CROW CANYON NEAR MOUTH OF KOEHLER COAL MINE.

Showing relations of the coal bed (*c*) to the Trinidad sandstone (*b*) and the basal conglomerate (*d*) of the Raton formation.



B. VIEW NORTH OF KOEHLER.

Showing the Pierre shale (*a*), the Trinidad sandstone (*b*), the coal-bearing Vermejo formation (*c*), the lower part of the Raton formation (*d*), and a part of the "barren series" (*e*).



SECTIONS OF THE COAL BEDS IN THE VERMEJO FORMATION IN THE KOEHLER COAL DISTRICT, N. MEX.

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

stone. Still farther to the east and to the south the base of the formation consists of a coarse sandstone that is variable in character and irregular in occurrence. It is usually hard and where well exposed forms a small but well-defined shelf in the side of the mesa just above the outcrop of the Trinidad sandstone. The shelf at the top of the projecting point of the mesa, half a mile north of Yankee, is formed by this sandstone. It is here separated from the underlying Trinidad by 2 or 3 feet of carbonaceous shale apparently a remnant of the Vermejo formation that escaped erosion. However, 2 miles southeast of Yankee, in a cliff formed by the basal sandstone of the Raton and the Trinidad sandstone (see Pl. XX, *B*, p. 192), the Raton formation rests unconformably on the Trinidad sandstone without any carbonaceous shale between. Similar occurrences were observed at the side of the wagon road just south of Rathbun Canyon, near the Colorado line at the eastern edge of the Raton quadrangle, and elsewhere in the eastern part of the Raton field.

The rocks through a thickness of about 100 feet above this basal sandstone consist mainly of shale in which there are several beds of coal, only one of which, the Sugarite bed, is known to be of commercial value. This zone of coal-bearing rocks is recognizable throughout the Raton and Brilliant quadrangles.

A series of beds consisting principally of coarse-grained sandstone 300 feet or more in thickness occurs above the Sugarite zone. Because these rocks do not contain coal of commercial value they have been called the "barren series." The sandstone forms the cliffs which are so conspicuous throughout the Raton Mesa region and the prominent escarpment that faces the plain southwest of Raton. Several coal beds that occur above the "barren series" make up the principal coal beds of the Raton formation. They occur in a zone of shale and soft sandstone that is locally called the "upper coal group." This zone is readily recognized at the outcrop by the coal and carbonaceous shale that crop out in it.

In the eastern part of the Raton field the Raton formation is overlain by the mesa lavas and the poorly consolidated Quaternary sand and gravel that occur beneath the lavas in some places. West of the mesas the coal-bearing rocks are overlain by beds of coarse material which may be equivalent to the Poison Canyon formation. Since the publication of the geologic folios describing the Trinidad coal field in southern Colorado, the Raton and Poison Canyon formations have generally been regarded as unconformable with each other. Mainly because of the lithologic character of the Poison Canyon and its stratigraphic relations it was correlated with the Denver formation of the Denver Basin. G. B. Richardson found in it fossil plants that are identical with species in the Denver formation and later the same species of plants were found in the Raton formation. These,

together with many others, prove that the Raton, the Poison Canyon, and the Denver formations are of approximately the same age.

It seemed difficult to reconcile these facts until the work was done for this bulletin, when in the highlands west of Raton it was found that in many places the beds above the upper group of coals are arkosic and conglomeratic and closely resemble those of the Poison Canyon formation. No line of demarcation corresponding to the unconformity supposed to exist in the Trinidad field between the Poison Canyon and older rocks was found, and it seems probable that there is little difference in age between them and that the differences in physical character are due to local variations in sedimentation. Similar relations have been described by Richardson[5] from Castle Rock, Colo., where he shows that the Dawson arkose and the Denver formation constitute essentially one formation although they differ in physical character.

STRUCTURE.

The geologic structure in the Raton field is very simple. This field constitutes the southern part of the somewhat irregular basin of coal-bearing rocks known as the Raton Mesa region. The stratified rocks of the area described dip slightly in a northwesterly direction, toward the center of the basin, but are not warped or faulted to any considerable extent. Several small faults have been encountered in the mines, but the displacements are slight and most of them seem to be due to surface movements similar to slumping. In many places the rocks of the sides of the mesa and in the canyons seem to be gradually settling and producing numerous small displacements along fault lines. This settling is indicated in many places by open fissures a few inches to a foot or more in width. The movement also crushes the coal in some places and renders beds irregular that seem to have been originally of uniform thickness. The movements are accelerated by the removal of coal, and in the vicinity of the mines small open fissures are numerous at the surface. This faulting and crushing of the coal has been noted near the outcrop in several mines. A large number of small faults were encountered in the New Gardiner mine east of Blossburg. The old Hartsel mine southeast of Sugarite was abandoned, according to report, because of irregularities in the coal bed, whereas the same bed as developed in the Sugarite mine half a mile away is regular in character and thickness.

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[5] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, Castle Rock folio (No. 198), 1915.

COAL.

RATON COAL BED.

GENERAL FEATURES.

The Raton coal is the most valuable bed in the Raton field. The coal is a coking bituminous coal that compares favorably with the best bituminous coal of Ohio and other parts of the United States. It is used extensively on railway locomotives, and a large quantity of the coke made from it is shipped for use in the smelters of the southwest.

The Raton coal occurs in the Vermejo formation or the lower of the two formations that were formerly grouped together under the name Laramie. It was the first coal to be developed in the Raton field, and because the mines were near Raton, the only town of consequence in the field at that time, the bed was called the Raton coal. As development proceeded farther and farther toward the southwest the name was applied to the lowest coal at each locality which was supposed to be the exact equivalent of the coal first developed near Raton. Closer study, however, makes doubtful whether the bed developed in one district is the same as that developed in a neighboring district. In some places there are two coal beds separated from each other by rock ranging from a few feet to 30 feet or more in thickness and in other places there are three or more beds, but whichever bed happened to be thickest where a mine was opened has been called the "Raton bed."

The coal beds of the Vermejo formation may indeed be broad lenses, as some believe, and their attenuated edges may overlap, but they were not examined in the old mines with this conception in mind, and the records of the abandoned workings are not sufficient to determine beyond question at the present time the shape of the beds. Furthermore, the long stretches of outcrop between developed districts have not been prospected extensively enough to settle this question. On the other hand, it is possible that the coal beds are not so lenticular as has been supposed and that some of the higher beds were removed by the erosion that preceded the deposition of the younger formation. The indications of lenticularity and the evidence of the occurrence of separate beds grouped under the name "Raton coal," as well as the indications of the removal of some of them by erosion, are given in detail in the following pages, but the general usage is followed and the name "Raton coal" is used in a general way for coals of the Vermejo formation, although for convenience local names are used to designate the part of the bed developed in the several districts. Thus Koehler, Van Houten, Gardiner, Blossburg, and Dawson are local names that have been

used to designate the Raton coal from the mines located at these places.

The Raton coal is described by districts in order from southwest to northeast. There are three well-defined districts separated from each other at the outcrop by barren areas, although the coal is continuous between them back from the outcrop. These districts are Koehler, named from the mining town; Willow, named from the canyon in which the Willow mine opens at the town of Van Houten; and Blossburg, which is here described as extending southward to include the undeveloped area in the canyon of Canadian River (locally called Red River) and eastward to include the area in the vicinity of Raton. The fourth important district in which the Raton coal is mined is Dawson. As this district is outside of the area shown on the maps, its description is given after that of the mapped districts.

KOEHLER DISTRICT.

LOCATION.

The Koehler district extends from Crow Canyon southward and westward to Saltpeter Creek and includes all territory which will eventually be reached by the Koehler mine. For convenience the district may be regarded as extending to the Dawson property, the boundary of which follows the crest east of Saltpeter Canyon.

RELATIONS OF THE COAL BEDS.

Two coal beds occur in the northern part of this district separated by a maximum vertical distance of about 30 feet. As previously explained, these are both in a sense the "Raton coal," and the two may join to the south and form the thick bed of the main part of the Koehler mine. The lower bed, so far as is known, attains a minable thickness only locally in Crow Canyon unless indeed it thickens toward the north and becomes the main bed exposed in the northern tributaries of that canyon. The upper one, which is the main bed of the developed part of the district, may be called the Koehler coal because of its development in the main part of the Koehler mine. This bed has been extensively prospected along the outcrop and much information collected concerning it. The data obtained from the surface are presented first, after which the character of the bed is described and an outline given of its relations to neighboring rocks as shown in the mine workings, followed by a description of the mine.

The coal bed lies at an altitude a little less than 7,000 feet, 500 feet or more above the general level of the plain to the east. The rock beds are somewhat warped so that the dip of the coal bed varies slightly in direction and degree from place to place, but in general it is inclined slightly toward the west, the outcrop crossing Prairie Crow Canyon at an altitude of about 6,750 feet and Crow Canyon

at about 6,700 feet. The bed outcrops in the sides of the canyons along a very irregular line.

The coal bed on which the Koehler mine is developed is the lowest and indeed the only one in the Vermejo formation near Koehler, although a lower coal occurs farther north. The Vermejo is here only a few feet thick, although in the western part of the Raton coal field it reaches a maximum measured thickness of 425 feet,[6] and contains ten or more coal beds of varying thickness. The coal lies only a few feet above the Trinidad sandstone, which here as elsewhere throughout the field makes a prominent cliff, and below a massive conglomerate that constitutes the base of the Raton formation and that lies unconformably on the Vermejo. The stratigraphic relations of the coal beds are best shown in the sections that have been plotted in Plate II (p. 12), and these are described in the following pages.

STRATIGRAPHIC POSITION OF COAL BED.

Several columnar sections that show the relation of the coal beds to the neighboring rocks were measured in the Koehler district, some of them by Orestes St. John, the geologist of the company owning the land, others by the writer and his assistants. The results of St. John's work are recorded on two comprehensive charts. The first, which bears the date 1898, indicates the location of the outcrop line, the altitudes of the coal at the several localities examined, the platted sections showing the character of the coal bed as measured in prospect openings, and other useful information. The second chart bears the date 1902, and, although intended primarily to cover the Willow district farther north in a manner similar to the first, includes the northern part of the Koehler district. Later a portion of the outcrop in Prairie Crow Canyon was prospected by the coal company in greater detail and the results recorded on a map dated 1907. These results are used in the following descriptions in addition to the data obtained by the writer.

The Pierre shale and the Trinidad sandstone are well exposed in this district, and the rocks of the Vermejo formation, although soft and therefore poorly exposed in many places, are well known through mining operations. The conglomeratic sandstone at the base of the Raton formation makes a conspicuous cliff above the outcrop of the coal, as shown in Plate III, *A* and *B*, and is easily recognizable.

[6] U. S. Geol. Survey Prof. Paper 101, pl. 17, 1918.

PROSPECTS AND SECTIONS MEASURED AT THE OUTCROP.

AREA SOUTH OF CURTIS CANYON.

The Raton coal bed is not well exposed in the Koehler quadrangle south of Curtis Canyon, and little can be said of it. It is reported to be 3 feet thick at locality 1 and 4 feet 10 inches thick at locality 2, where the following section was measured:

Section of rocks at locality 2, south of Five Dollar Canyon.

	Ft.	in.
Raton formation:		
Sandstone, cliff-making	100+	
Shale	3	
Coal	1±	
Shale, not continuously exposed	35	
Coal	2	
Sandstone and shale, not continuously exposed	40	
Sandstone, yellow, thin-bedded	7	
Sandstone, yellow, massive	12	
Shale, carbonaceous	3	
Sandstone, yellow, massive, fine grained, quartzose, with streaks of very coarse sand	10	
	213±	
Unconformity.		
Vermejo formation:		
Shale, not continuously exposed	21	
Coal	4	10
Shale, drab	9	
Sandstone, white, massive, coarse, friable	18	
Sandstone, white, massive, with partings of shale	19	
Shale, drab	4	
Sandstone, yellow, hard	1	
Shale, drab to black, carbonaceous at top	4	
Sandstone, brown, hard, massive	1	6
Shale, with partings of sandstone	7	
	89	4
Trinidad sandstone:		
Sandstone, containing *Halymenites major* Lesquereux and invertebrates	80+	
Pierre shale:		
Transitional zone.		
Shale.		
	382±	

The exact correlation of this section with neighboring sections is open to question. Either the Vermejo formation is unusually thick here or some of the rocks referred to it belong in the Trinidad sandstone. Elsewhere in the region the main coal bed is only a few feet above the top of the Trinidad sandstone. The suggestion that the lower 54 feet of the Vermejo formation of this section is really Trinidad finds support in relations observed at locality A, three-

fourths of a mile to the east, where 2 feet of coal and carbonaceous shale was observed below 20 feet of sandstone which forms the upper part of the sandstone cliff, there interpreted as Trinidad sandstone.

At locality 3, where the outcrop crosses Five Dollar Canyon—formerly called Turkey Canyon—the main coal bed is 4 feet thick. No satisfactory measurements of the coal were made in the east wall of Five Dollar Canyon, but the croppings indicate that the thick bed is persistent there. Also a thin bed containing a few inches of coal was noted in several places below the main bed, and in some places a higher bed containing a few inches of coal occurs just under the basal conglomerate of the Raton formation.

In the east wall of Five Dollar Canyon, a white friable sandstone was observed above the main coal bed. This sandstone is persistent throughout the Dawson district and is described fully on pages 121–122. It was not observed east or north of Five Dollar Canyon.

The coal in Curtis and Waldron canyons was prospected in 1907 by the St. Louis, Rocky Mountain & Pacific Co. From the chart furnished by this company are obtained the details shown in Plate IV. In view of the occurrence of the thick bed of coal in Five Dollar Canyon and of the still greater thickness shown east of Curtis Canyon, the extreme thinness of the coal in the west wall of Curtis Canyon is not readily understood. If the bed of coal shown in sections 1 and 5 in Plate IV represents the main bed, it is evident that this bed thins out rather abruptly toward the southeast. On the other hand, the known occurrence in this region of a thin bed of coal 5 to 10 feet below the main coal and the occurrence of a still lower bed of thin coal at locality 4 raises the query whether the bed in these sections may be one of these lower beds.

Two sections showing the rocks above and below the coal in this region were measured, one east of Curtis Canyon near locality 19 and one east of North Curtis Canyon near locality 33. They are as follows:

Section of rocks at locality 19, east of Curtis Canyon.

	Ft.	in.
Raton formation:		
Sandstone, yellow, massive, fine grained	20	
Covered	55	
Sandstone, yellow, massive, fine grained	10	
Shale, sandy	16	
Coal		8
Sandstone, thin-bedded, alternating with yellow sandy shale	38	
Shale	4	
Coal		6
Shale, drab	1	
Sandstone, massive, fine grained	3	
Shale, drab to yellow	4	
Coal	1	

	Ft.	in.
Raton formation—Continued.		
Shale, not continuously exposed	37	
Coal	1	5
Shale, yellow to brown	10	
Sandstone, massive, coarse grained	25	
Sandstone, thin-bedded, and sandy shale, not continuously exposed	27	
Sandstone	5	
Shale	12	
Sandstone	12	
Covered	10	
Sandstone, fine grained, hard, and quartzose	10	
	302	7
Unconformity.		
Vermejo formation:		
Shale, brown to black	12	
Coal		8
Shale, black, carbonaceous	6	
Coal		8
Shale, brown to black		6
Coal		8
Shale	10	
Sandstone, yellowish white	6	
Coal, bony		6
Shale, brown to black		6
	43	
Trinidad sandstone	77	
Pierre shale:		
Transitional zone.		
Shale.		
	422	7

Section of rocks at locality 33, east of North Curtis Canyon.

	Ft.	in.
Raton formation:		
Sandstone and shale; several hundred feet.		
Sandstone, massive, coarse grained, base irregular	53	
Unconformity.		
Vermejo formation:		
Shale, with layers of thin sandstone and ironstone nodules	18	
Coal		9
Shale, buff-colored	7	
Coal		6
Shale	1	
Sandstone, white, granular	9	
Shale, buff-colored	5	
	49	6
Trinidad sandstone	90	
Pierre shale:		
Transitional zone	25	
Shale.		
	217	6

AREA NORTH OF CURTIS CANYON.

Still farther north, in Waldron Canyon, at locality 40, St. John reports the following section:

Section of rocks in Waldron Canyon, at locality 40.

	Feet.
Sandstone.	
Shale	5
Coal	8
Shale.	
	13

The sandstone of this section is doubtless the base of the Raton formation, which is conglomeratic in this region and which in many places farther north rests unconformably on the coal.

The coal bed thins slightly toward the east. According to St. John, at locality 41 it is 7 feet 6 inches thick (see Pl. IV), and at locality 42 it is 7 feet, but at neither of these localities is the character of the bed or its relation to neighboring rocks indicated. Toward the north the diminution in thickness is slight. At locality 43, in Ashenfelter Canyon, the bed is reported to be 7 feet 9 inches thick, but a shale parting appears which does not occur farther to the southwest at locality 40. This shale parting increases in thickness toward the east and was measured at localities 44 and 45 as shown in the graphic sections of Plate IV. The measurements from which these sections are plotted are found on the mine map and presumably are comparable to the mine sections, which are described below.

The sections made from the mine measurements indicate only the part of the coal bed removed in mining. The floor of the Koehler mine is shale in most places, but the roof varies greatly. The material above that represented in the sections may be bone or a part of the coal left in process of mining, or it may be shale, sandstone, or conglomerate, all of which constitute the roof in one part or another of the mine. The probable character of the material overlying the coal at these localities can readily be inferred from the sections that follow.

At locality 46 St. John reports the section shown in Plate IV in which there is a thickness of 8 feet 6 inches of clean coal overlain by 2 feet 6 inches of shaly coal. No mention is made of the shale parting just described, but it may be present here as it is both west and north of this locality. In some of the sections reported years ago the total thickness of the coal bed was given without regard to partings, and it is not now possible to verify the observations without reopening the prospect entries, which have long since been destroyed.

Still farther north, at locality 47, the section of the coal bed is very similar to that measured at locality 46. Just north of this locality a large dike cuts the coal bed. The next point along the outcrop at

which a section was measured is in the north wall of Bear Den Canyon, at locality 48, where St. John reports the following section. The conglomerate of this section is the one now known to lie unconformably on the Vermejo beds.

Section of rocks at locality 48, in Bear Den Canyon.

	Ft.	in.
Conglomerate.		
Shale	4	
Coal		6
Shale	1	4
Coal	1	3
Shale, brown		7
Coal	8	3
Shale.		
	15	11

At locality 49, on the point of the mesa to the east, a thickness of 9 feet of coal is reported, but no details of the bed are given. This measurement was made before the study of the economic resources of the region was undertaken by the writer, but it is probable that the bed is here the same as that at locality 48. A columnar section showing the stratigraphic relations of the coal to the rocks above and below it was measured at this locality as follows:

Section of rocks at locality 49, near Koehler, N. Mex.

[For graphic section see Pl. II, p. 12.]

	Feet.
Raton formation:	
Sandstone, conglomerate, coarse-grained, quartzose, containing siliceous pebbles as much as 1¼ inches in diameter	28
Unconformity.	
Vermejo formation:	
Covered	5
Coal	9
Shale, not continuously exposed	18
Trinidad sandstone	80
Pierre shale.	
	140

Near Koehler the Vermejo formation is irregular in thickness, due to erosion after it was laid down. In some places the upper part of the coal bed was eroded. The shale, which at locality 48 separates the conglomerate from the coal, occurs in some places farther west in the mine, but in other places it is absent and the conglomerate rests with irregular base on the coal. In the western part of the mine, near locality 114, a parting of sandy shale separates the coal into two benches. These benches were followed westward in the mine to a point where the parting is 6 feet thick. This parting doubtless represents the 25 feet of sandstone and shale between the two coal beds at the outcrop in the canyon at locality 50 (see Pl. II), where the following section was measured:

Section of rocks at locality 50 in Prairie Crow Canyon.

	Ft.	in.
Conglomerate, under surface covered with worm borings.		
Unconformity.		
Shale		3
Coal		11
Coal, bony	1	6
Coal		11
Shale		2
Coal		9
Shale and cross-bedded sandstone	25	
Coal		5
Shale		6
Coal	1	11
Shale	5±	
Sandstone (Trinidad).		
	37±	

The coal bed is well exposed in many places in the north wall of Prairie Crow Canyon near Koehler, where it outcrops in a zone of shaly rocks. (See Pl. III, *A*, p. 12.) The Trinidad sandstone forms a cliff below the line of outcrop of the coal, and the conglomeratic sandstone at the base of the Raton formation forms an equally conspicuous cliff above it. But only one bed of coal occurs here and this seems to include both the benches just described in the same way that both occur together south of the canyon.

At locality 52 the writer measured a section including the Trinidad sandstone at the base and the conglomerate at the top. The 6 feet of coal found at this locality probably represents only the lower part of the bed, which is much thicker than this on either side of this locality. The section is as follows:

Section of rocks at locality 52, in north wall of Prairie Crow Canyon.

[For graphic section see Pl. II, p. 12.]

	Feet.
Conglomerate	30±
Shale and sandstone	22
Coal	6+
Shale	8
Sandstone	5
Shale	3
Sandstone (Trinidad)	65
Shale or sandstone (?)	70
	209±

About 200 feet farther east the bed contains 11 feet of clean coal, as shown in section 52 in Plate II, and at the head of the gulch to the west, St. John reports a thickness of 12 feet of coal which is somewhat shaly at the middle. In this gulch the conglomerate that was 22 feet above the coal at locality 52 is only 6 feet above the coal, and still farther west, at locality 130, described below, the conglomerate

rests on the coal, which is reduced in thickness near this locality to 2 feet 6 inches or less. Mine entries were not driven into coal thinner than 2 feet 6 inches. The unconformity shown by the sections just described is illustrated in figure 3.

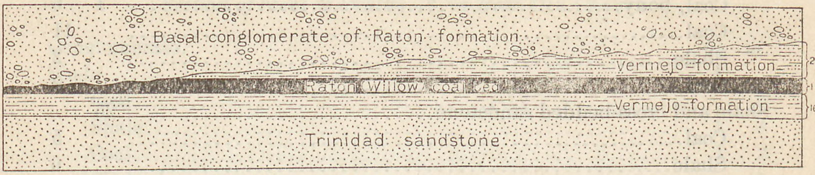


FIGURE 3.—Diagram showing relations of beds exposed in the north wall of Prairie Crow Canyon, where the basal conglomerate of the Raton formation rests unconformably on the coal-bearing shale of the Vermejo formation. The coal, which is here shown in black, thins toward the left to such an extent that mining is there discontinued.

At locality 53 the coal is reported to be 11 feet 10 inches thick (see Pl. IV), but no details of the bed are given. However, in the gulch still farther to the east, at locality 54, the bed is 12 feet 2 inches thick and is separated into two benches by a thin parting of shale, as shown in section 54 of Plate IV.

Still farther to the east the rocks extending from the upper part of the Pierre shale to the cliff-making sandstones of the "barren series" of the Raton formation at the top of the mesa are well exposed, as shown in Plate III, *A* (p. 12), and a columnar section was measured in the side of the canyon north of the town of Koehler at locality 55. The coal bed, which has a maximum measured thickness of 14 feet in this vicinity, does not occur in this section, but a bed of ash was found that obviously resulted from the burning of this coal. The section is as follows:

Section of rocks at locality 55, in side of canyon north of Koehler.

[For graphic section of lower part see Pl. II, p. 12.]

	Ft.	in.
Raton formation:		
Sandstone, yellow, massive	30	
Covered	75	
Sandstone, yellow, massive	15	
Sandstone, yellow, thin-bedded, with partings of sandy shale not continuously exposed	35	
Sandstone, yellow, massive	14	
Shale, drab to brown	10	
Sandstone, yellow, massive	18	
Shale and sandstone, not continuously exposed	44	
Sandstone	20	
Covered	8	
Sandstone	3	
Shale and shaly sandstone	16	
Sandstone, conglomeratic, coarse-grained, quartzose, with siliceous pebbles up to 1 inch in diameter	26	
Unconformity.		

	Ft.	in.
Vermejo formation:		
Shale and shaly sandstone	22	
Ash (representing burned coal)		6
Shale	1	6
Coal, dirty		6
Shale, brown to black, sandy	6	
Trinidad sandstone, with shaly partings	45	
Pierre shale.		
	389	6

The distance to which the burning has extended along the outcrop was not determined because of poor exposures in the south wall of Ox Canyon. Certainly, however, it extended back from the outcrop nearly to locality 138, where the burned area has been reached in the mine.

At the point where the outcrop of the coal bed crosses the stream in Ox Canyon, near locality 56, a columnar section was measured in the north wall of the canyon. The Vermejo formation is thicker here than it is west of Koehler, a mile farther south, the difference being due to the thickening of the beds below the main coal bed and to the appearance of a thin bed of coal below the main coal. Although only 3 feet of coal is reported in this lower bed where the section was measured, it is known from other measurements near by to be considerably thicker than this. The basal conglomerate of the Raton formation has here practically the same thickness and character that it has near the Koehler mine farther south and rests unconformably on the shale which overlies the main coal bed. The columnar section measured at this locality is as follows:

Section of rocks near locality 56, in the north wall of Ox Canyon.

[For graphic section see Pl. II, p. 12.]

	Ft.	in.
Raton formation:		
Sandstone, conglomeratic	27	
Unconformity.		
Vermejo formation:		
Coal	3	7
Shale		1
Coal		10
Shale	5	
Sandstone, white, coarse-grained, massive, shaly toward the top	27	
Coal		8
Shale, brown to black	4	
Shale and massive sandstone not continuously exposed	16	
Trinidad sandstone.		
	84	2

In the south wall of this canyon, near locality 56, the main coal bed was measured at the side of the stream, and the results are shown in the platted section on Plate IV. Apparently the upper part of the coal bed was eroded away before the conglomerate, which here

rests unconformably on the coal, was deposited. The lower surface of the conglomerate is covered with a network of cylindrical bodies found in many places throughout the Raton field, especially where the conglomerate rests on coal. Further evidence of partial removal of the coal is brought out by the varying thickness of the bed in this region, as shown in Plate II (p. 12), where the line connecting the base of the conglomerate of the several sections indicates the irregularities of the surface on which the conglomerate was laid down.

At locality 57 the conglomerate rests on coal that is more than 5 feet in thickness. The base of the coal bed was not seen. A little farther downstream in the first side gulch on the north St. John reports a thickness of 5 feet of coal at locality 58, and of more than 5 feet at locality 59. At neither of these localities does he indicate the relation of the bed to the neighboring rocks, but this relation is well shown farther east, where a good exposure of the coal and its accompanying rocks was found by the writer at locality 60 and the following section measured by him:

Section of rocks at locality 60, in north wall of Ox Canyon.

	Ft.	in.
Conglomerate	30	
Unconformity.		
Shale		8
Coal	3	4
Coal, bony		5
Coal		8
Shale		10
Coal	3	
Shale	1	
Coal	3	
Shale, carbonaceous	2	
Sandstone	8	
Shale, carbonaceous	8	
Sandstone (Trinidad).		
Total thickness of beds	60	11
Coal	12	3

Although somewhat nearer to the Trinidad sandstone than the bed just described at locality 56, this coal bed bed is obviously the one in which the Koehler mine is developed and the one on which the conglomerate, which is here separated from it by 8 inches of shale, rests unconformably at the localities just described farther up the canyon. The carbonaceous shale at the base of the section is at the horizon of the 8-inch bed which was observed near locality 56 and which farther to the north thickens and locally attains economic value. It is referred to elsewhere as the lower coal bed.

St. John found the main coal to be 8 feet thick in the gulch at locality 61, a little farther to the east, but for some distance farther to

the southeast the coal has been burned. However, its full thickness occurs at locality 62, where St. John measured the thickness shown in section 62 in Plate IV. Although he does not state that the sandstone is conglomeratic, it occupies the position of the conglomerate that is conspicuous throughout this region, and it has therefore been represented as conglomerate.

In addition to the data just given, more recent information has been acquired regarding the coal in Ox Canyon by the owner, the St. Louis, Rocky Mountain & Pacific Co., which has furnished it for this report. The outcrop was resurveyed in 1907, and the thickness of the main coal at the several localities where prospect

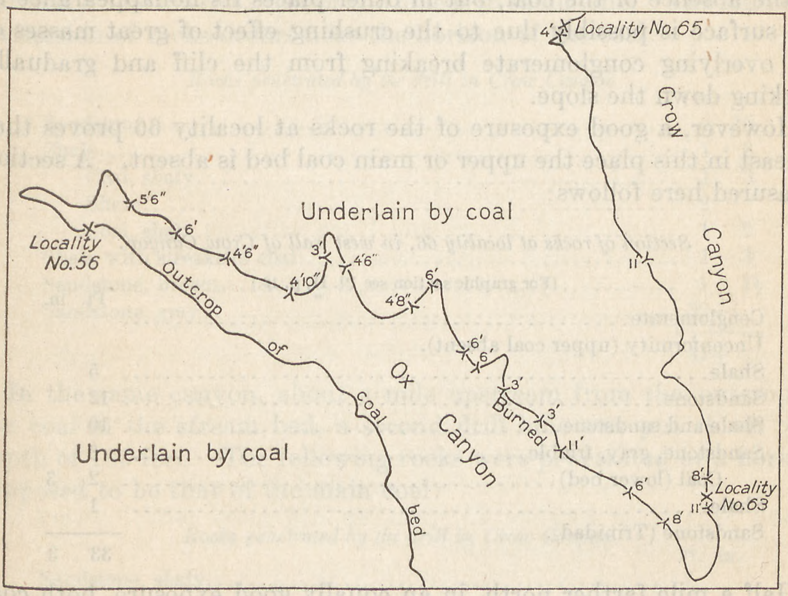


FIGURE 4.—Outcrop line of the Raton coal bed between Ox Canyon and Crow Canyon. The thicknesses of coal given are those measured in openings on this bed and represent only the main benches of coal.

openings were made is noted on the company's map along the line of outcrop. Apparently only the thickest bench of coal was measured, and the engineer's map shows nothing of the relation of this coal to other benches or to the rocks above or below the coal bed. For this reason these measurements were not included in the foregoing descriptions, but they are given in figure 4.

The coal is not well exposed near the point of the mesa between Crow Canyon and Ox Canyon, and it does not occur in some places where the exposures were good, but a prospect opening was made at locality 63 and the section of the bed as measured there by St. John is given in Plate IV.

No satisfactory exposures of the coal and associated rocks were found for a considerable distance northwest of locality 63, although St. John reports a thickness of 7 feet 10 inches for the bed at locality 64. He gives no details that indicate its character, but the writer found the conglomerate resting on 8 inches of coal in the north wall of the gulch at locality 65 and in the south wall a bed of coal, only 2 feet of which was visible, is separated from the conglomerate by 5 feet of shale. On the map previously referred to (fig. 4), the engineers for the coal company report 4 feet of coal at this locality. Several places were examined along the outcrop farther to the northwest without finding the coal. In some places this failure seems to be due to the absence of the coal, but in other places its nonappearance at the surface is possibly due to the crushing effect of great masses of the overlying conglomerate breaking from the cliff and gradually working down the slope.

However, a good exposure of the rocks at locality 66 proves that at least in this place the upper or main coal bed is absent. A section measured here follows:

Section of rocks at locality 66, in west wall of Crow Canyon.

[For graphic section see Pl. II, p. 12.]

	Ft.	in.
Conglomerate		
Unconformity (upper coal absent).		
Shale	5	
Sandstone	12	
Shale and sandstone	10	
Sandstone, gray, friable	3	
Coal (lower bed)	2	3
Shale	1	
Sandstone (Trinidad).		
	33	3

Half a mile farther north, in an equally good exposure, both coal beds occur, although the lower one was not well enough exposed to be measured in detail. The section of the upper bed is given as 67 in Plate IV. The columnar section follows:

Section of rocks at locality 67, in Crow Canyon.

	Ft.	in.
Conglomerate.		
Unconformity.		
Shale	1	
Coal	4	8
Not exposed	5	
Sandstone, gray, friable, shaly	25	
Coal and shale, not well exposed.		
Sandstone (Trinidad).		
	35+	

Near this locality St. John reports a thickness of 5 feet 3 inches of coal in the upper bed, which is here separated from the conglom-

erate by 2 feet 9 inches of shale, and farther northwest, at locality 68, he reports 4 feet 3 inches of coal in what is probably the same bed.

In the bottom of the canyon west of locality 68 both beds of coal are exposed in the bed of the stream. The full thickness of the lower bed is exposed, but the coal is shaly and shows signs of thinning out toward the west. A thickness of 3 feet of coal in the upper bed was seen at locality 69, but neither the top nor the bottom of the bed is exposed. The lower coal is only 1 foot 8 inches thick.

About 2,000 feet upstream from the outcrop of the coal in the bed of the stream a drill hole was put down to a depth of 129 feet 5½ inches. The base of the lowest coal was 96 feet 4 inches below the surface. The lower 32 feet of the hole is in sandstone. The following succession of rocks occurs near the horizon of the coal:

Rocks penetrated by the drill in Crow Canyon.

	Ft.	in.
Sandstone		10
Shale	1	8
Coal, shaly	1	3
Shale	2	
Coal, shaly	1	2
Shale with streaks of coal	1	3
Sandstone, brown	1	1½
Sandstone, gray	32+	
	41+	

In the same canyon, about a mile upstream from the outcrop of the coal in the stream bed, a second drill hole was put down to a depth of 186 feet. The following rocks were penetrated at a horizon supposed to be that of the main coal:

Rocks penetrated by the drill in Crow Canyon.

	Ft.	in.
Sandstone, shaly	7	
Shale		2
Coal, shaly	1	4
Shale	1	8
Coal, shaly	1	4
Shale	1	1½
Coal, shaly		9
Shale	2	2
Sandstone	1	10+
Total thickness of beds	17	4½+
Coal	3	5

The records of the drill holes when considered in connection with the sections measured in the south wall of Crow Canyon, indicate that the coal probably thins toward the west in this part of the field to such an extent that it is of little commercial value under present conditions. The 32 feet of sandstone at the bottom of the first hole indicates that the drill entered the Trinidad sandstone, but there is

no indication here of the presence of two beds of coal which at locality 67 are 30 feet apart.

In the north wall of Crow Canyon farther east two beds of coal were found like those that occur in the south wall of this canyon. In the west wall of the north side tributary, at locality 70, the lower bed contains a thickness of 1 foot 10 inches of coal and lies 2 feet above the Trinidad sandstone. St. John reports a thickness of 4 feet 1 inch of coal in the upper bed near this locality. The writer found a thickness of 5 feet 10 inches of clean coal with shale above and below it in the stream bed at locality 71. (See section on Pl. IV.) The conglomerate lies 8 feet above the upper coal in this gulch.

In the east wall of this gulch, a little farther south, at locality 72, St. John reports a thickness of 4 feet 3 inches of coal in the upper or main bed, but the relation of the bed to neighboring rocks is not indicated. Still farther southeast the conglomerate rests on the coal and finally replaces the upper bed entirely. At locality 73 the conglomerate rests on a bed of coal 2 feet 6 inches thick, which seems to be the lower bed, although this is not certain, and at locality 74, north of the junction of Antler and Crow canyons, it is close to the lower bed, but the actual contact was not found.

The relations in the west wall of West Antler Canyon are similar to those just described, but exposures were so poor that no details of the coal bed were obtained. However, in this canyon, at locality 75, the conglomerate rests unconformably on the upper bed of coal. The bed here has essentially the same character and thickness that it has at locality 76, a little farther south, where a more complete section was measured. The rocks are well exposed in the east wall of the canyon at locality 76, near an old mine entry, where the following section was measured:

Section of rocks at locality 76, in West Antler Canyon.

[For graphic section see Pl. II, p. 12.]

	Ft.	in.
Conglomerate.		
Unconformity.		
Coal	1	
Bone		1
Coal		10
Bone		1
Coal		9
Coal, bony		3
Coal	1	
Shale	4	
Sandstone	20	
Coal (lower bed)	2	
Shale	4	
Sandstone	4	
Shale	2	
Sandstone (Trinidad).		
	40	

The rocks near the coal beds or between the Trinidad sandstone and the overlying conglomerate are not well exposed in the east fork of Antler Canyon nor in the north wall of Castle Canyon, and the writer found no place where details of the coal bed could be satisfactorily obtained. St. John reports a thickness of 4 feet 6 inches of coal in the west wall of the east fork of Antler Canyon, at locality 77, and 6 feet 9 inches in Castle Canyon, at locality 78.

At the forks of Castle Canyon and also in its east wall the coal is well exposed in many places. At locality 79, where the bed crosses the west fork of the canyon, St. John reports the measurements shown in section 79.

At the fork of the canyon, locality 80, the writer measured the section shown as 80 in Plate IV.

Although the coal bed is here only 4 feet above the Trinidad sandstone, there are some reasons for believing that it is the upper one of the two beds in Crow Canyon farther to the west which lies 30 feet or more above the Trinidad sandstone. However, the lower bed, which farther west lies practically on the Trinidad, possibly thickens toward the east and becomes the thick bed that here lies close to the Trinidad, and the upper bed may not be represented. Unfortunately, the beds between Castle Canyon and locality 76, Antler Canyon, the last place described where both beds were found, are not exposed well enough to determine this point.

In the east branch of Castle Canyon, at locality 81, a mine entry, which later was connected with the workings of the Willow mine to the north, was driven in on the coal bed for a considerable distance at the time of the writer's investigation. At the mouth of the mine the conglomerate lies on the coal, which is 6 feet 1 inch thick at the mouth of the opening. The character of the bed and its relations to the rocks above and below it are shown in section 81 of Plate IV, page 12.

In Castle Canyon, about 1,600 feet northeast of the last locality described, a drill hole was put down to a depth of 130 feet 6 inches. A heavy sandstone above the coal bed here doubtless represents the conglomerate. Under this sandstone is a 7-inch bench of coal, which is separated by 1 inch of shale from the main bench found at locality 81. The rocks penetrated at the horizon of the coal are as follows:

Rocks penetrated by the drill near locality 81, in Castle Canyon.

	Ft.	in.
Sandstone, massive:		
Coal		7
Shale		1
Coal	5	8
Coal, slaty		1
Sandstone, shaly	1	
Sandstone, brown		6
Total thickness of coal	8	3

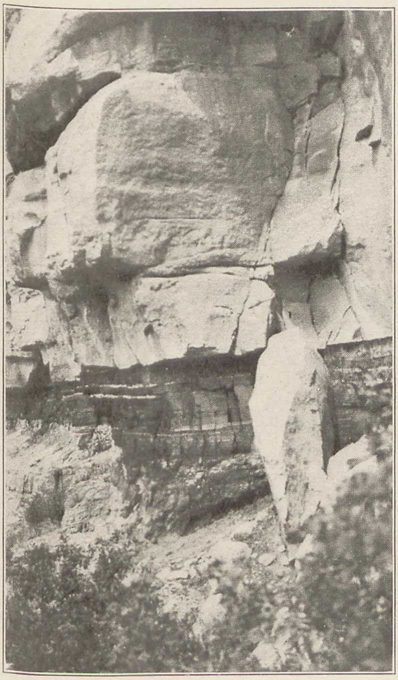
In the east wall of the canyon the coal bed is well exposed, and several sections of it were measured. The results have been platted as sections 82 to 86 inclusive on Plate IV (p. 12).

No measurements were made farther south in Castle Canyon, but about three-fourths of a mile southwest of locality 86 St. John reports a thickness of 12 feet 11 inches of coal, though he does not indicate the relation of the bed to neighboring rocks. No details of the coal bed were obtained in the north wall of Schomburg Canyon because of poor exposures. The conglomerate overlying the coal in this canyon is very resistant, and large masses of it cover the slopes (see Pl. III, *B*, p. 12) and effectively conceal the beds that would naturally outcrop in the slopes. The boulders weather to a rough craggy surface owing to the superior hardness of the chert and quartzite pebbles in it. The conglomerate forms a conspicuous shelf that can generally be recognized in the canyon walls in this region.

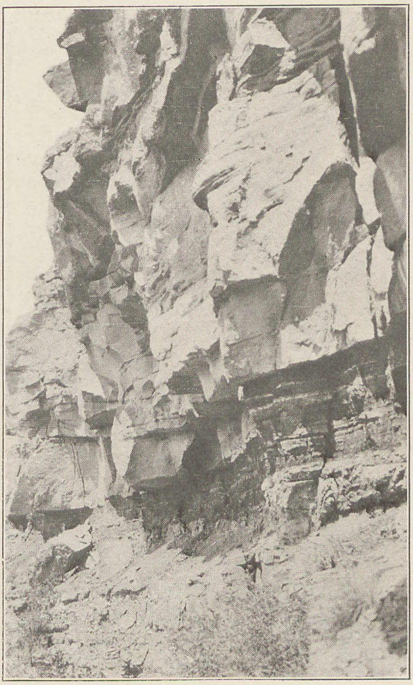
A precipitous cliff has been formed in the east wall of the west fork of Schomburg Canyon by a large landslide. The face of this cliff exposes the Trinidad sandstone with the lowest coal bed of the Vermejo formation a few feet above it. Resting uncomformably on this coal is the basal conglomerate of the Raton formation. The relations of the coal bed to the rocks below and above it are shown in Plate V.

St. John states that the coal in the canyon at locality 88, just north of this cliff, is 6 feet 10 inches thick and that conglomerate lies above and shale below it. The same bed was measured by the writer at four localities rather close together in the face of the cliff. These show a gradual thickening of the bed toward the south. The coal occurs in two benches, separated by a few inches of bone that can be traced continuously. In this way it was demonstrated that the variations in thickness are due to variations in the upper surface of the coal bed, presumably caused by erosion. The measurements are as follows:

A. BANDED CHARACTER OF COAL BED, DUE TO BEDDED IMPURITIES.



B.



C.

B, C. CHARACTER OF OVERLYING CONGLOMERATIC SANDSTONE.

CLIFF IN SCHOMBURG CANYON, SHOWING THE RATON COAL BED LYING UNCONFORMABLY BELOW THE CONGLOMERATE AT THE BASE OF THE RATON FORMATION.

Sections of coal in Schomburg Canyon.

[For graphic sections see Pl. II, p. 12.]

	Locality 89.	Locality 90.	Locality 91.	Locality 92.
	Ft. in.	*Ft. in.*	*Ft. in.*	*Ft. in.*
Conglomerate:				
Coal	2 4	3 2	4 10	5 10
Bone	7	3	5	2
Coal	9	1	1 1	1 3
Shale.				
	3 8	4 5	6 4	7 3

In the south fork of Schomburg Canyon the conglomerate cuts down again into the coal, so that at locality 93 the coal is only 2 feet 2 inches thick and has conglomerate above it and shale below. (See Pl. IV.) Farther south the exposures are poor, and the writer found no place where the thickness of the coal could be measured satisfactorily, but St. John reports the following section measured in a prospect entry at locality 94. The sandstone of this section doubtless represents the conglomerate.

Section of coal at locality 94, in north wall of the canyon south of Schomburg Canyon.

	Ft.	in.
Sandstone.		
Coal	1	9
Shale		6
Coal	5	-
Shale.		
Total thickness of bed	7	10
Coal	7	4

Farther east he found 5 feet 6 inches of coal at locality 95 and 4 feet in the bed of the canyon at locality 96. South of locality 96 the coal is irregular in thickness and in some places is absent. St. John reports a thickness of 5 feet of coal in the west slope of the ridge about half a mile south of the south boundary of the Brilliant quadrangle, and still farther south the writer found 1 foot 6 inches with the conglomerate resting on it. But at the southern end of this ridge the coal is only a few inches thick, and it finally disappears, allowing the conglomerate to rest on the carbonaceous shale that normally underlies the coal, and beyond on the Trinidad sandstone. At the southern end of this ridge, and for some distance in its eastern slope, the rocks are well exposed and the contact of the conglomerate and the Trinidad sandstone is plainly seen. No coal was found in the eastern slope of this ridge for several miles farther north.

KOEHLER MINE.

The coal in the Koehler district has been developed in the northern part of the Koehler quadrangle. The mines open in Prairie Crow Canyon at the town of Koehler and the entries are driven in on the

coal bed north and south of the canyon. The workings (see map, Pl. I) extend nearly 3 miles from north to south and about 2½ miles from east to west.

ROOF AND FLOOR OF MINE.

The conglomerate at the base of the Raton formation lies unconformably on the coal in some places and in others on beds that normally underlie the coal bed. It ranges in thickness from a few feet to 40 feet or more and is so resistant that it forms a strong roof for the mine, but of far more important economic significance is the fact that at certain localities it replaces the coal in whole or in part. In other words, prior to its deposition the coal was eroded away in some places. (See Pl. II.) In many places within the mine thin coal is capped with conglomerate and thick coal with shale. This is explained on the assumption that the erosion did not in all places cut away all of the shale that originally covered the coal bed.

The rock in the roof of the Koehler mine differs greatly in kind and in character from place to place. It consists of shale, bony coal, sandstone, or conglomerate in different places. In some places where thin shale forms the roof it is "brushed" down in the process of mining but where it is thick enough to form a good roof is left in place. There is no regular "draw slate" and no bad falls have occurred in the mine. A few "pots," or slick-sided conical masses of shale in the roof, have been encountered that fall readily but they have caused no serious inconvenience. Props and cross-bars are used in the main entries and props with caps in the rooms that need timbering. In places where the roof is sandstone or conglomerate no props are required.

The floor of the mine consists of relatively thin shale, which separates the coal from the massive Trinidad sandstone below. It is regular in occurrence and forms an even floor from which the coal separates readily. It shows a general tendency to move under pressure, but there are few places in the mine where squeezing has seriously interfered with mining operations.

COAL BED.

The coal bed is only slightly affected by faults in this mine, although some have been encountered with a throw of a few feet. In several places the fault lines can be traced through the coal and the roof shale, but not into the overlying conglomerate. In these places the displacements occurred previous to the deposition of the conglomerate. The coal bed has also been affected by the intrusion of igneous rock. One large dike and several small ones have cut the bed. Apparently the molten rock spread laterally, displacing the coal so that the width of igneous rock as exposed in the mine is considerably greater than the thickness of the dike where it appears at

the surface. The coal is coked for a few feet on either side of the igneous rock but otherwise seems to be unaffected by the intrusions.

A general summary of the character of the coal bed developed in the Koehler mine shows that even though the sections were not all measured from the same datum plane and therefore can not be definitely correlated, and though some of the partings of shale and bone are persistent throughout considerable areas, the bedded impurities on the whole are irregular in distribution. In few places does the bone separate readily from the coal, and where it forms a large percentage of the volume of the bed the coal can not be profitably mined. The cleat faces are only moderately well developed and little use is made of them in mining. Their general trend is N. 75° W., the same as that of the dikes, several of which occur in the vicinity of Koehler. At some places masses of sandstone known as "spars" extend into the coal and at others they cut entirely across the bed. The "spars" seem to be associated with the overlying conglomerate and, so far as noted, occur only where the conglomerate rests in contact with the coal or is very close to it. The "spars" are not so prominent in the Koehler mine as they are in the Willow mine, but are of the same nature. (See pp. 59-60.)

CHARACTER AND COMPOSITION OF THE COAL.

The coal is bituminous and will coke readily. It is compact and tough and has relatively dull luster and irregular fracture. It varies in character somewhat from place to place, but in general it is finely laminated owing to the presence of layers having a vitreous luster alternating with layers of dull porous material resembling charcoal. Woody fragments also occur in which the fibrous structure is still visible under a lens. The laminated structure is particularly conspicuous on exposed surfaces where the soft charcoal layers weather out and the harder vitreous layers form ridges.

The composition of the coal is indicated by six analyses given in the table of analyses (pp. 240-246). Its coking quality renders it less desirable as a domestic fuel than some other coals in the Raton field, but its high heating value renders it especially valuable for a smithing and steaming fuel. It does not crumble readily on exposure to the weather and stands shipping without notable deterioration. The coal is separated at the tipple into lump (about 26 per cent), nut (about 28 per cent), and slack. Some of the lump and nut coal is used for smithing, but most of it is used on railway locomotives. The slack is coked in beehive ovens at the mouth of the canyon east of the town of Koehler.

Certain information regarding the character of the coal was obtained before the mine was opened, and this is presented here because of its historic interest and also because the analyses of the

weathered coal may be useful for comparison with those of the unweathered coal. The coal for analysis was collected in a prospect opening in Prairie Crow Canyon from five horizons in the bed, numbered in order from base upward. The results of the analyses are as follows:

Analyses of weathered coal from Prairie Crow Canyon.

[Reported by Orestes St. John.]

	Sample 1.	Sample 2.	Sample 3.	Sample 4.	Sample 5.
Moisture	1.70	2.68	6.24	9.23	8.71
Volatile matter	35.04	34.49	30.15	31.03	33.99
Fixed carbon	50.40	54.47	55.15	48.76	51.12
Ash	12.16	7.86	7.94	10.54	8.72
Sulphur	.70	.50	.52	.44	.46
British thermal units	12,384	12,435	11,094	10,385	10,450

Samples 1 and 2 yielded coke which was regarded as satisfactory and which had the following composition:

Analyses of coke made from weathered coal in Prairie Crow Canyon.

	Sample 1.	Sample 2.
Moisture	1.31	0.76
Volatile matter	.94	1.54
Fixed carbon	76.34	85.62
Sulphur	.46	.30
Ash	20.90	12.78

The coal from the upper part of the bed did not coke. However, when unweathered coal was obtained it was found that all parts of the bed produced excellent coke.

The sections measured in the mine do not show the character of the entire bed, for most of them indicate only the portions of coal removed in mining. For one reason or another parts of the bed are left. The mine measurements, however, serve to indicate the thickness and character of the part of the bed actually mined, and are more significant as showing commercial value than measurements made in prospect openings along the outcrop of the bed where the relation of the coal to neighboring rocks can be shown. For this reason several of the measurements made in different parts of the mine have been shown in the sections in Plate II (p. 12).

SECTIONS MEASURED IN THE MINE.

In mine No. 1, at the end of the main entry, locality 97. the coal bed was measured as follows:

Section of coal bed at locality 97, in main entry of Koehler mine No. 1.

	Ft.	in.
Shale.		
Coal, bony, not mined		6
Coal		7
Bone		5
Coal (sampled)	1	9
Bone		1
Coal (sampled)		6
Bone		2
Coal (sampled)	1	
Bone		1½
Coal (sampled)	1	8
Bone		3
Shale.		
Total thickness of bed	7	½

A sample of the coal representing four benches was collected for analysis. The results of this test are given in analysis 33017 (p. 240).

The coal bed is relatively regular in thickness and character over a considerable part of the area developed in the southern part of mine No. 1. It is 6 feet 11 inches thick at locality 98 and 7 feet 2 inches thick at locality 99. Farther north at locality 100 the coal removed in mining was 5 feet 2 inches thick. A considerable part of the bed may not have been removed at this locality, for the bed is 8 feet thick at locality 40 in Waldron Canyon. At locality 44 also a thickness of 5 feet 6 inches of coal in the lower bench of the bed, separated from an upper bench by a shale parting, suggests that the bed may be similarly divided at locality 100 and that only the lower bench was mined.

The minable portion of the coal thickens to the north to 6 feet 6 inches at locality 101 but becomes bony at the bottom toward the east and north, where 8 inches of bone is reported at locality 102. The coal becomes bony also toward the northwest, but here the bone occurs near the top of the lower bench instead of the bottom, as shown in the section at locality 104.

At a point near locality 101 a sample of the coal for analysis was collected by J. C. Roberts on May 28, 1911. The sample included coal 6 feet 2 inches thick with poor coal below and bony coal above it. The results of this test are given as analysis 12336 in the table of analyses (p. 240).

The bed continues westward with little change in character to locality 103, where it consists of a lower bench of clean coal 6 feet 3 inches thick and an upper bench of 2 feet of bony coal. The bony layer persists toward the west, where at locality 105 the following section was measured:

Section measured at locality 105 in the Koehler mine.

	Ft.	in.
Shale.		
Coal		9
Bone		11
Coal	4	
Shale.		

A sample of this coal was collected for analysis by the writer on September 27, 1912. It represents the entire thickness of the coal below the bone. The results are given as analysis 14796 in the table of analyses (p. 240).

Farther north the bone seems to disappear, and the coal is reported to be 6 feet 6 inches thick at locality 106 and 7 feet thick at locality 107, but farther west it becomes bony again, there being 1 foot 6 inches of bony coal over 5 feet 6 inches of clean coal at locality 108. Near the end of the entry, at locality 109, the coal was so impure that development work in this part of the mine was stopped. The character of the bed at the end of this entry is shown in section 109 (fig. 2). In this entry nearly 1,000 feet from the main entry two samples of coal for analysis were collected by J. C. Roberts on May 28, 1911, at points 300 feet apart near locality 106. The first sample (12335) represents 6 feet of clean coal which has 1 foot of poor coal below it and 2 feet of bony coal above. The second sample (12337) represents a thickness of 5 feet 9 inches of coal.

In the main entry of mine No. 1, north of the intrusive mass of igneous rock, the coal is somewhat bony and the mined portion ranges in thickness from 5 feet to 8 feet. At locality 110 it is 6 feet 10 inches thick but becomes bony toward the west, as seen in the first entry south of the igneous rock. At locality 111 clean coal 5 feet 6 inches thick is underlain by 1 foot of bone, and at locality 112 the coal is 5 feet 10 inches thick and the bone 8 inches thick. Several measurements near this locality gave the same results. Near the end of this entry, at locality 113, the coal is reported to be only 4 feet thick and the bone has increased in thickness to 3 feet 6 inches, as shown in the platted sections. As these conditions were regarded as too unfavorable for profitable mining the entry was not driven farther west. In the next entry to the north the bone decreases to 6 inches in thickness, although the coal is still thin, only 3 feet 6 inches being found at locality 119. The coal, however, thickens toward the east and is 5 feet thick at locality 115.

As the coal bed seemed to become thinner and to have a less favorable character toward the west, the advisability of pushing mining operations in that direction became doubtful, and a drill hole was put down in Prairie Crow Canyon about a mile west of the outcrop of the coal in this canyon to test the character of the bed in advance of the mine workings. This prospect indicated condi-

tions still less favorable for mining, for the bed is here separated into three benches, as follows:

Section of coal bed penetrated by drill in Prairie Crow Canyon.

	Ft.	in.
Shale, sandy	7	2
Coal, shaly	1	4
Shale, brown	1	8
Coal, shaly	1	4
Shale, brown	1	1½
Coal, shaly		9
Shale, brown	2	2
Sandstone, gray	1	10½
Total thickness of beds	17	5
Coal	3	5

In the cross entries between mine entries 1 and 2 the coal seems to have been rather constant in thickness, although bone is reported in some places. At locality 116 a thin stratum of bone was found near the top of the coal (section 116, Pl. IV), but it does not seem to have been persistent. It is not reported from some of the localities farther south and the coal bed removed in mining ranges in thickness in the central part of the mine from 5 feet 4 inches to 5 feet 8 inches and increases toward the east to 6 feet at locality 117.

East of the main entry of mine No. 2 the coal maintains an even thickness but appears somewhat bony in some places. At locality 118 it is reported to be 6 feet thick and at locality 119 to be 7 feet. Still farther to the east a considerable amount of bone occurs in the coal, as shown in the sections at localities 120 and 121. At the end of the entry, at locality 122, the working reached practically to the surface where, at locality 49, as previously described, the coal bed is 9 feet thick. The two sections, 123 and 124, in the next entry to the south indicate that the bed maintains relatively uniform character in this direction.

Between main entries 1 and 2, south of the intrusive igneous rock, the coal is uniform in thickness and notably free from bedded impurity, although it is bony in some places. At locality 125 it is reported to be 6 feet 6 inches thick, and it is 7 feet 6 inches thick at locality 43, at the outcrop a little farther south in Ashenfelder Canyon. At locality 126 it is 6 feet 9 inches thick and it has the same thickness at locality 127, although still farther to the west, at locality 103, it becomes bony at the bottom.

Farther south, in mine No. 2, a thick bench of bony coal is developed at locality 128, where a section was measured. Still farther south and east, at locality 129, another section was measured.

Sections measured at localities 128 and 129.

Locality 128.

	Ft.	in.
Coal	2	11
Bone		7
Coal	1	9

Locality 129.

	Ft.	in.
Shale.		
Coal (sampled)		10
Bony coal	1	4
Coal (sampled)	5	4
Shale.		

A sample of the coal above and below the bone was collected at this locality for analysis and the results are given under analysis 33018 (p. 241).

North of Prairie Crow Canyon a mine entry was started in the gulch where the coal at the outcrop is thick enough to indicate favorable conditions for mining, although the conglomerate here rests upon it. As the entry was driven toward the west the coal became gradually thinner. At locality 130 it is 3 feet 6 inches thick and a little farther west, where it is only 2 feet 6 inches thick, the entry was abandoned. The variation in thickness is due to erosion of the bed before the conglomerate was deposited upon it.

Another entry, now known as mine No. 3, was driven from the outcrop in the same gulch and more favorable conditions were found. In this entry the conglomerate rests on the coal, but at locality 131 the coal has increased in thickness to 4 feet 6 inches. (See Pl. IV.) It increases slightly in thickness still farther northeast, where it is 5 feet thick at locality 132, but becomes somewhat bony still farther in the same direction. At the end of the main entry, locality 133, a considerable thickness of bone was found at the base of the coal (see section 133), but a little farther south the bone decreases in thickness (see section 134).

Still farther south, in the main gangway of this part of the mine, at locality 135, the coal is reported to be 4 feet 7 inches thick, but the bone at the bottom is not noted on the mine map. It appears, however, farther east at locality 136, where 4 feet of coal is underlain by 1 foot 6 inches of bone. However, the occurrence of the bone seems to be irregular, for it is not reported in several of the measured sections in this part of the mine and apparently only the more conspicuous bony layers were recorded by the engineers on the mine map. It is noteworthy also that the coal exclusive of bone in sections 133 to 136 inclusive is regular in thickness, and the variations shown in the sections are probably due to differences of opinion as to what should be included in the measured sections rather than to any real variation in the character of the coal bed.

The writer measured a section in detail at locality 137, where he collected a sample of the coal for analysis. This locality is in room No. 71, off the second gangway east of the main entry of mine No. 3. It is as follows:

Section of coal bed at locality 137, in Koehler mine.

	Ft.	in.
Shale.		
Coal (sampled)		10
Coal, bony, not separable in mining (sampled)		4
Coal (sampled)		6
Bone		1
Coal (sampled)	1	5
Bone		½
Coal (sampled)	1	1
Coal, bony (about 20 per cent coal)	1	4
Coal (sampled)		9
Bone		1
Coal (sampled)	3	2
Shale.		
	9	7½

The sample for analysis, which includes the parts of the bed indicated in the foregoing section, was collected by the writer on September 25, 1913. The results are given as analysis 17781 in the table of analyses (p. 240).

Near the eastern extremity of the mine, at locality 138, the coal is reported to be 6 feet thick, but east of this locality ash and other evidences of burning were encountered. Doubtless the fire that destroyed the coal near the surface in the point of the mesa north of the town of Koehler extended into the rocks to this locality.

DEVELOPMENT OF MINING.

The Koehler mine was opened in 1905 and during the following year was equipped with an electric power plant of large capacity. This plant, however, was abandoned in 1914, and the power for all mining operations is obtained by electric transmission from a plant at Trinidad, Colo. In order that the fine coal screened at the tipple might be used to the best advantage a coal washer of the Stewart type was built, and 210 coke ovens of the beehive type were constructed for coking the fine coal. Electrically driven fans were installed for ventilation, and the air is distributed through carefully constructed airways and cement overcasts. Pipes in the mine workings furnish water under pressure for sprinkling the mine. No gas of any consequence has been encountered, and the mine is sprinkled once a week to keep it free from dust explosions. Electric lights are used.

The mine is developed by a double drift entry run in from the outcrops of the bed, which lies so nearly horizontal that the workings

can be extended in any direction without inconvenience. The coal is mined by the ordinary room and pillar system. The little water that has been encountered in the mine is pumped out with ease, owing to the nearly horizontal position of the coal bed.

Years ago the mining was done by hand, but during the summer of 1913 Goodman short-wall chain machines were installed and have been in operation ever since. These machines are electrically driven undercutters adapted for use in rooms of any size. After undercutting the coal is shot off the solid. The powder used is Monabell No. 5, and it is handled entirely by shot firers, who do all loading of holes and firing of shots. They also have authority of inspection in order to insure the proper preparation of the holes for shooting. Their work is done entirely at night, when the mine is nearly free of other laborers.

Mules are used in the mine for distributing the empties and for hauling the loaded cars to the main entries, where they are handled by electric motor. At the tipple the coal passes over a shaking screen directly to the cars where it is weighed. The slack is sent to the coke ovens, but the lump and nut coal is shipped, principally for railway use. At the time of investigation the mine had an estimated capacity of 3,000 tons a day but was actually producing only 1,800 tons a day.

WILLOW DISTRICT.

LOCATION.

The Willow district, which includes localities 140 to 180, lies northeast of the Koehler district, from which it is separated at the outcrop by the divide between Crow Canyon and Willow Canyon. Although the Raton coal bed is continuous through this divide, where its occurrence has been proved by the development of the Willow mine, the district is separated from other parts of the field to the north and to the south by an area in which coal is absent. The coal of this district has been developed in the Willow mine, which opens at the town of Van Houten, in the South Fork of Willow Canyon.

STRATIGRAPHIC POSITION OF COAL BED.

The coal bed of the Willow district is the same as that described in the northern part of the Koehler district and is believed to be the same as that developed in the Koehler mine. It is one of the main bodies of coal of the Raton field that are generally grouped together as the Raton coal and is the only bed of coal in this district that occurs in the Vermejo formation. In order to determine its stratigraphic relations to the rocks above and below it the rocks at the outcrop were examined in detail at several critical points, and several

columnar sections were measured. These sections are shown graphically in Plate II (p. 12).

The coal and the accompanying rocks of the Vermejo formation thin out in the southern end of the ridge east of Crow Canyon. They were not found in the eastern slope of this ridge although the Trinidad sandstone and the basal conglomerate of the Raton formation are readily recognized. At the point where these formations cross Falls Canyon, a few feet of carbonaceous shale separates the Trinidad sandstone from the overlying conglomerate. The rocks near this horizon are not well exposed in the walls of the canyon, and as the coal occurs a short distance to the west, in the wall of Schomburg Canyon, it may yet be found in some places in Falls Canyon. However, in the eastward-facing cliffs on the point of the mesa between Crow Creek Canyon and Willow Creek Canyon the rocks are perfectly exposed for a long distance, and the Vermejo formation is absent, the basal conglomerate of the Raton formation resting unconformably on the Trinidad sandstone. A good exposure showing this relation occurs where the rocks are cut by a dike in the steep face of the cliff east of Falls Canyon.

The Pierre shale forms long barren slopes at the foot of the cliffs, and the Trinidad sandstone is normally developed and appears as a white band in the side of the mesa. The conglomerate is resistant and cliff making and when viewed from a distance is not readily distinguishable from the Trinidad sandstone, but on close examination the two are clearly separable at the contact, which appears in Plate VII, *A* (p. 48) as a more or less irregular line.

The unconformity may not appear conspicuous to one unfamiliar with the rocks themselves, for they are not strikingly different in appearance and the line of unconformity is not very irregular, but when the lithologic character of the two formations is clearly understood there is no difficulty in determining the line of separation, and when the rocks are traced laterally along the outcrop the Vermejo formation is seen to lie normally between them. The conglomerate is harder than the underlying sandstone and in some places juts out as an overhanging cliff. Near the localities where the photographs were taken the following section was measured:

Section of rocks in the eastward-facing cliff 2 miles southeast of Van Houten, at locality 139.

[For graphic section of lower part see Pl. II, p. 12.]

	Ft.	in
Raton formation:		
Sandstone, massive, cliff-making	70	
Shale, soft, with thin beds of sandstone	50	
Sandstone	6	
Shale	8	
Sandstone, thin-bedded	12	

	Ft.	in.
Raton formation—Continued.		
Shale	12	
Coal	2	6
Shale	8	
Sandstone, thin-bedded near the top, massive below	30	
Shale, carbonaceous, with thin beds of coal	24	
Sandstone	10	
Shale, dark	15	
Sandstone, coarse-grained, massive, cliff-making, locally conglomeratic	40	
Shale	20	
Sandstone, white, coarse-grained, friable	20	
Shale, dark	3	
Conglomerate and coarse-grained sandstone	50	
Unconformity:		
Trinidad sandstone	71	
Pierre shale.		
	451	6

The basal conglomerate of the Raton formation in this area is about 50 feet thick and consists of a matrix of coarse sand in which siliceous pebbles occur in more or less irregular-shaped masses. So far as observed the pebbles are more numerous near the base but are found here and there through the entire thickness of the conglomerate. Conglomeratic sandstone was also found 133 feet above the base of the Raton formation.

The rocks that form the high bench shown in Plate III, *B* (p. 12), are massive cliff-making sandstones that make an almost continuous escarpment along the southeastern margin of the Raton coal field. These rocks constitute the so-called "barren series." The softer shaly beds which occur at many other localities between the conglomerate and the overlying cliff-making sandstones are characteristically developed at this locality, and coal was found in them at two horizons. At the lower horizon only thin beds occur, but at the higher one there is a bed 2 feet 6 inches in thickness. This coal will be referred to later in the description of the Sugarite coal bed.

The absence of the Raton coal and of the rocks referable to the Vermejo formation in this region, when considered in connection with their occurrence on either side and the unusual thickness of the conglomerate, suggests the probability that the conglomerate was deposited in a local hollow, perhaps a valley of erosion which had been cut down through the coal bed. No indication of the coal was found for a considerable distance north and west of this locality, but in a south side branch of Willow Canyon, near locality 140, the conglomerate and Trinidad sandstone are separated by a wedge of the Vermejo formation, and thence northward and westward this wedge thickens and includes the coal bed developed in the Willow mine.

This coal bed will be described first as it appears at the outcrop and afterward as it appears in the workings of the Willow mine. The character of the bed is shown by the sections in Plate VI, and where possible its relations to the rocks above and below it are also shown.

PROSPECTS AND SECTIONS MEASURED AT THE OUTCROP.

In the first branch canyon south of Van Houten, where the Vermejo formation begins to appear between the Trinidad sandstone and the overlying conglomerate, the coal is thin. At locality 140 1 foot 6 inches of coal was found with conglomerate above and shale below it, as shown by the section in Plate VI. (See also fig. 5.) In the north wall of the gulch, just north of this locality, St. John reports a thickness of 5 feet 9½ inches of coal with conglomerate above it and shale below. A few hundred feet farther north the coal is 6 feet 2 inches thick and is separated from the conglomerate by 1 foot of shale. The conglomerate forms a cliff which is readily traceable in the side of Willow Canyon and generally rests on the coal in this vicinity. The coal south of this canyon has been mined out, and most of the sections

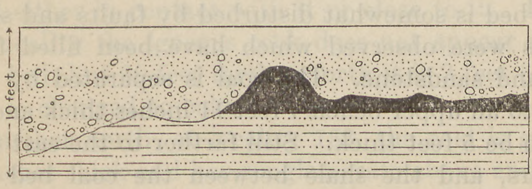


FIGURE 5.—Unconformity between the Vermejo and Raton formations near Van Houten (locality 140) where the Raton coal bed was eroded. (Drawn from a photograph.)

measured at the outcrop are omitted. The general character of the bed in this part of the district is indicated by the section measured in the gulch east of the mouth of mine No. 4 (section 141). West of this mine opening, where the coal crosses the bed of the canyon, the conglomerate at locality 142 is separated from the coal by 8 inches of shale, as shown in the section. The bed here consists of two benches of coal separated by shale. These benches will be considered in detail later in the description of mine No. 1.

In the north wall of this canyon a little farther to the east the writer examined a section at locality 143, where mine workings open at the surface. (See Pl. VII, *B*.) Here the relations of the Vermejo to neighboring formations are well shown. The upper part of the Trinidad sandstone is somewhat fissile and grades upward into the Vermejo through alternating layers of sandstone and shale, so that the exact line of separation is not readily determined. However, at least 5 feet of shale is referable to the Vermejo, and this together with the 13 feet of coal is all that constitutes the Vermejo formation at this locality. The basal conglomerate of the Raton

formation is 20 feet or more in thickness and rests directly on the coal, as shown in Plate II (p. 12). The shale parting in the middle of the bed is not present at this locality. (See section 143 in Pl. VI.)

The under side of the conglomerate is covered with the network of wormlike bodies previously described. Farther north in Spring Gulch, at locality 144, just west of the opening of mine No. 1, the coal is 12 feet thick and is separated from the overlying conglomerate by shale that is reported to be 20 feet thick. This report is confirmed in some measure by evidence gained from a drill hole put down in the gulch near locality 174, where a sandstone 35 feet above the coal bed may represent the conglomerate. Reports are somewhat conflicting as to the relation of the coal bed to other rocks in the part of the district that lies still farther upstream.

Farther east the shale that separates the coal bed from the overlying conglomerate is reduced in thickness to 4 feet. Near the point where the coal bed lies in the bed of the stream a narrow gorge is worn out of the Trinidad sandstone, and good exposures of the upper part of the coal bed occur on either side only a few hundred feet apart. The bed is somewhat disturbed by faults and slips, and shrinkage fissures were observed which have been filled from the overlying shale and sandstone. The coal is separated by 1 foot 3 inches of shale into an upper bench 4 feet 11 inches thick and a lower bench reported to be 5 feet thick. Still farther to the east the shale parting disappears, and the shale between the coal bed and the conglomerate becomes thinner. These relations are shown by a section at locality 145 reported by St. John as follows:

Section of rocks measured at Van Houten.

[See section 145, Pl. II, p. 12.]

	Ft.	in.
Conglomerate.		
Shale	4	
Coal		8
Shale	2	
Coal	3	5
Shale		3
Coal	7	2
Shale.		
	17	6

At the point where the coal bed crosses the stream in the canyon still farther north, locally known as East Branch, the coal is reported by St. John to be 11 feet 2 inches thick, and at locality 146, about 100 feet east of this point, the writer measured section 146 in Plate VI. A short distance farther to the east St. John reports a section similar to this one, except that shale intervenes between the coal and the conglomerate. As this section was measured before the topographic map was made, its exact location can not be shown on

the map. Also at locality 147, near the point where the mouth of mine No. 5 was afterward located, he reports a thickness of 14 feet 6 inches of coal with conglomeratic sandstone above and shale below the bed. This sandstone is now known to be the conglomerate of the base of the Raton formation. Farther east, at locality 148, the coal thins to 8 feet 6 inches and becomes somewhat bony. At the end of the ridge, near locality 149, St. John reports the two sections that have been shown as 149. These sections show considerable variation in the character of the bed. Similar variations in character were found in the mine workings near this locality. The coal is burned in some places along the outcrop farther north and in other places has been destroyed by intrusions of igneous rock. At the point where the mine opens to the surface the conglomerate rests on the coal, as it does also farther north at localities 150 and 151. At locality 151 a thick shale parting develops in the lower part of the bed. (See section 151.) This shale contains thin beds of ash that probably represent burned coal. In many places in this vicinity the coal is coked, obviously by the heat of the igneous rock that lies either in contact with it or close to it. In the gulch west of this locality the igneous rock does not appear at the outcrop of the coal bed, but 60 feet farther north it is 2 feet 6 inches thick and the coal is changed to coke.

Still farther north, at locality 152, the coal is graphitic. It is 7 feet 7 inches thick and has conglomerate above and sandstone below it. The graphitic coal is represented as ordinary coal in the section in Plate VI. The igneous rock was not found here, but it is 2 feet 3 inches thick a few feet to the north, and it occurs northward along the outcrop for about one-eighth of a mile. Fragments of coke and graphite were found in many places at the surface, presumably derived from the bed in the immediate vicinity. The igneous rock increases in thickness toward the west and becomes a continuous sheet at or near the horizon of the coal bed in the north wall of North Willow Canyon, so that the commercial value of the coal is practically destroyed, although in a few places where the igneous intrusions follow other horizons the coal escaped destruction. In the north side gulch of this canyon, half a mile east of the point where the coal crosses the stream, the bed is exposed, but the igneous rock has destroyed the coal. A section which was measured in the north wall of North Willow Canyon near locality 153 illustrates this point. The section was measured before the topographic map was made; hence the exact locality can not now be shown. The section is as follows:

Section of rocks near locality 153, in north wall of North Willow Canyon.

[For graphic section see Pl. II, p. 12.]

	Feet.
Igneous rock, basalt	20
Conglomerate	4
Unconformity.	
Shale, black, carbonaceous	10
Igneous rock, basalt	10
Shale	2
Coal	7
Shale and intrusive igneous rock	20
Sandstone (Trinidad)	100±
Shale (Pierre).	
	173±

No good coal was found east of locality 154. On the prominent spur west of this locality the Raton bed is 9 feet thick, but the coal has been destroyed by intruded igneous rock. In the point of the mesa near locality 181 coal and igneous rock were also observed together. Some of the shale of the Vermejo formation was recognized in several places for about 1½ miles east of this locality, but in the south slope of Red River Peak and for a considerable distance west of this peak the basal conglomerate of the Raton formation rests directly upon Trinidad sandstone.

WILLOW MINE.

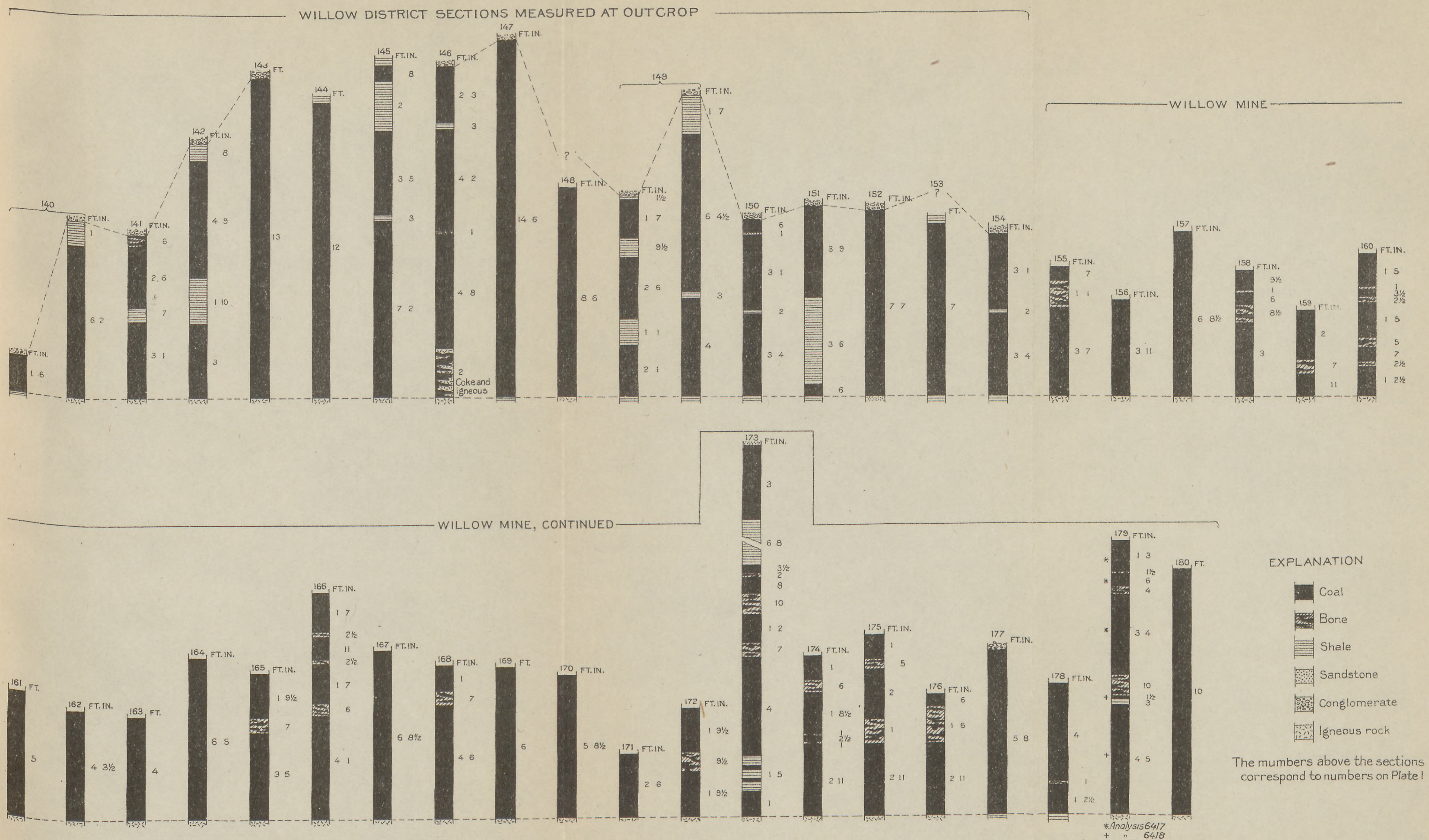
GENERAL FEATURES.

In the Willow district the coal is commercially developed only in South Willow Canyon, near the town of Van Houten. The bed lies at an altitude of a little less than 7,000 feet above sea level and slopes westward about 50 feet to the mile. The first openings were made in the south wall of Willow Canyon and in Spring Gulch. The mine became commercially productive in 1902 and has since been in operation. The main openings are located in the sides of the canyon and the entries have been driven on the bed back into the hills on either side.

CHARACTER OF THE COAL BED.

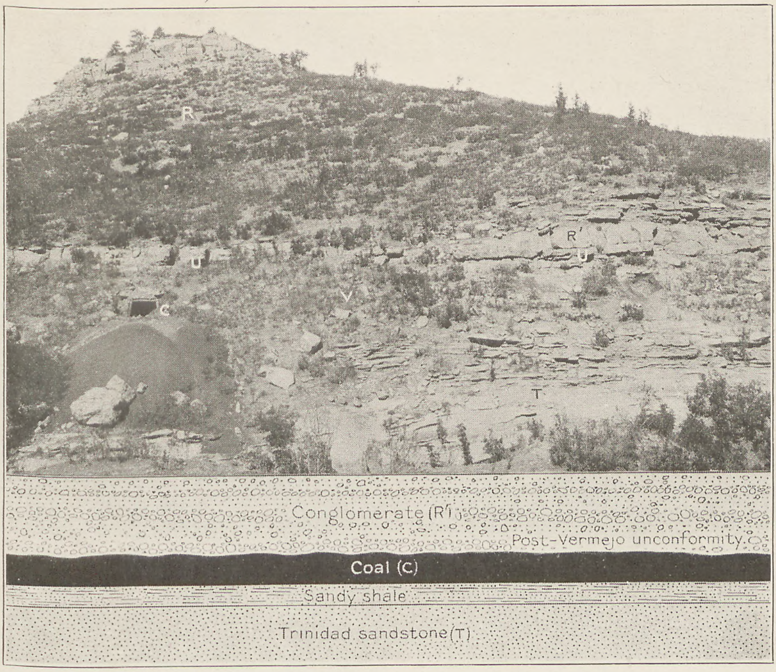
In No. 6 entry the coal bed thins toward the southeast and work was stopped where the coal became too thin for profitable mining. The bed is more uniform in thickness in entry No. 4, but toward the west the coal contains a considerable amount of shale and bone.

Mine entry No. 1 was started on a thick body of good coal, but back from the outcrop the bed is split into two benches by a shale parting, which thickens toward the northwest. It is reported that the upper bench becomes too thin for mining and the coal in the lower one becomes poor toward the west owing to an increase in the



SECTIONS OF THE COAL BED MEASURED AT THE OUTCROP OF THE VERMEJO FORMATION IN THE WILLOW COAL DISTRICT AND IN THE WILLOW MINE, N. MEX.

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

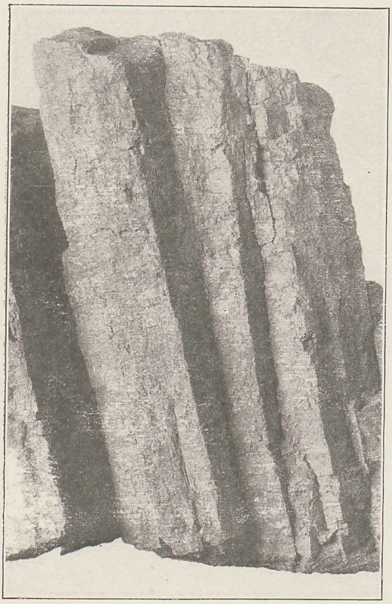


A. VIEW AND DIAGRAMMATIC SECTION OF OUTCROP OF RATON COAL BED AT VAN HOUTEN.

Showing its position between the Trinidad sandstone (T) and the conglomerate (R′) at the base of the Raton formation. V, Vermejo formation; U, coal in Vermejo formation; U, unconformity between Vermejo and Raton formations; R, Raton formation.

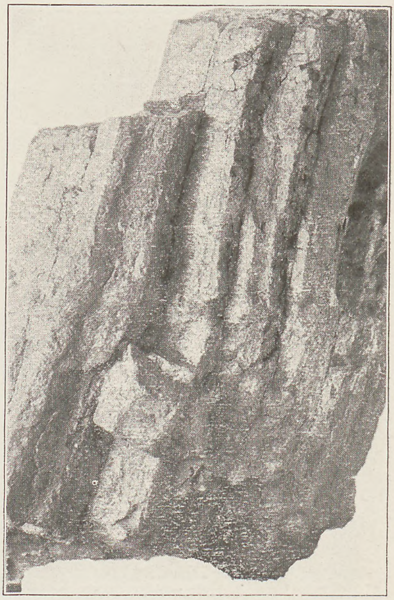
B. NEAR VIEW OF COAL BED AT LOCALITY 143.

Conglomerate (R′) rests unconformably (at U) on 13 feet of coal.



A. NATURAL COKE FROM WILLOW MINE.

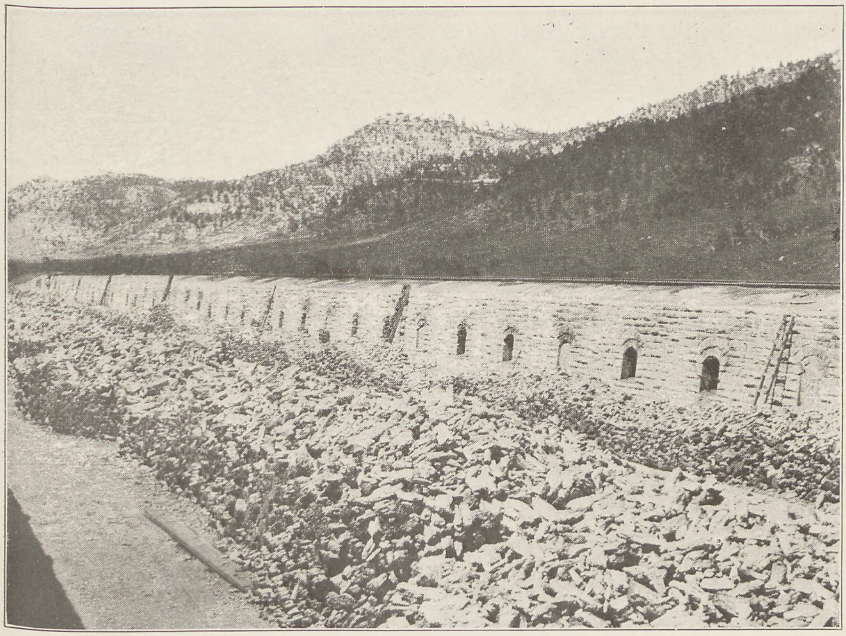
The coal is coked in many places near the masses of intrusive igneous rock.



B. GRAPHITE FROM COTTONWOOD.

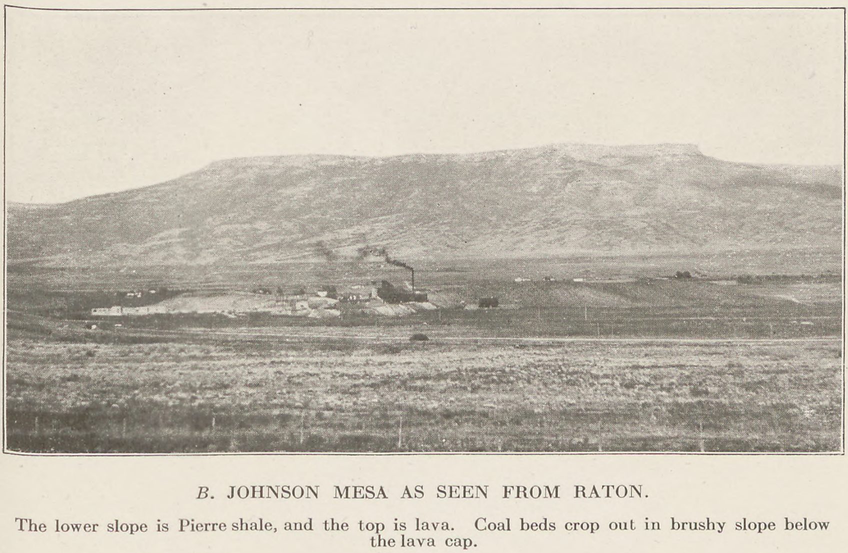
The Willow coal has been metamorphosed by the intrusive igneous rock. About one-third natural size.

C. COAL FROM APEX OF A "POT" IN OLD WAGON MINE, ON SUGARITE COAL BED AT LOCALITY 339, NORTHEAST OF RATON.



A. COAL AND COKE OVENS AT GARDINER.

Coal-bearing rocks in the background.



B. JOHNSON MESA AS SEEN FROM RATON.

The lower slope is Pierre shale, and the top is lava. Coal beds crop out in brushy slope below the lava cap.

content of bone and partings of shale, and this part of the mine had been abandoned at the time of the writer's investigation in 1913.

The coal bed in entries Nos. 5 and 7 is very irregular in thickness and character, and in many places igneous rock has been injected into it so that throughout considerable areas the coal is coked. Some of the igneous rock is in the form of dikes and some in the form of sheets that doubtless connect with a sheet which outcrops at the surface at the horizon of the coal in the north fork of Willow Canyon. However, this connection can not be demonstrated, for the igneous rock was not intruded in all places into the coal, and it is traceable underground only where it has been exposed by the removal of the coal. Where the coal is cut by dikes it is coked, the amount of the coke varying with the thickness of the dike. The coke is columnar next to the igneous rock and granular farther away, but the total thickness of the coke on either side seldom exceeds the thickness of the dike. The columnar coke from this part of the mine is illustrated in Plate VIII, *A* (p. 48).

Joints are well developed in the coal of the Willow mine, there being two to four major cleat faces to a foot and two to five minor faces to the inch. The joints are nearly parallel with the dip, ranging from N. 70° W. to N. 89° W. The major joints are traceable through some of the thinner partings of shale but not through the thicker ones, nor do they extend into the shale of the roof or of the floor. In some places the joints of one bench of coal are independent of those of other benches separated from it by thin partings of shale. The cleat faces not only fail to extend through the shale partings but they do not even correspond in number or position in the separate benches.

ROOF AND FLOOR OF MINE.

The roof of the mine differs in character from place to place. It consists of bony coal or shale in some places and conglomeratic sandstone in others. In the southeastern part of entry No. 6, where the coal thins to a reported thickness of 2 feet 6 inches, the roof consists of massive conglomeratic sandstone. Farther west in mine No. 4, and in the mines north of the canyon, where the coal is much thicker, the roof consists of bony coal or of shale which separates the coal from the overlying conglomerate, but in the eastern part of mine No. 7 this conglomerate again rests on the coal. In mine No. 1 the roof shale thickens to a reported maximum of 15 feet in the northwestern part of the workings and 20 feet in Spring Gulch near locality 146.

The irregular surface at the base of the conglomerate represents an ancient surface of erosion. When this surface was formed the coal in the northern part of the area mined in the Willow district was under thin cover, whereas that in the southern part was exposed to

erosion and farther toward the southeast the coal had been eroded away exposing the Trinidad sandstone at the surface. Thus the basal conglomerate of the Raton formation was deposited across the eroded edges of the Raton coal bed and its associated rocks as illustrated in figure 6 and Plate V (p. 32). The recognition of this unconformity renders intelligible the great diversity of character in the roof of the mine as well as the great differences in the thickness of the coal bed.

In mine No. 1 there are two benches of coal. The shale parting serves generally as the roof for the workings in the lower bench, but in some places the top of this coal is left to support the roof, the coal making a stronger roof than the shale. The entries are here timbered with props and crossbars and the rooms with props and caps. In some places the shale slacks and crumbles but in general the crumbling causes little trouble in mining. It is not jointed and usually falls in the form of plates, although occasionally it falls in irregular masses and some "pots" have been encountered. In other parts of the mine there are many horsebacks and rolls, and where the conglomerate

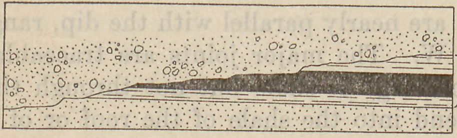


FIGURE 6.—Sketch section through Willow mine showing the full thickness of the coal bed to the right in the northwestern part of the mine and its disappearance toward the southeast to the left.

rests on the coal the contact is very uneven owing to the erosion of the bed prior to the deposition of the conglomerate. This condition was noted particularly in No. 6 mine, where hollows 2 feet or more in depth are filled with sand and pebbles as shown in figure 8. In this mine the coal is cut by dikelike bodies of pebbly sandstone locally known as "spars," which are usually connected with the conglomerate that forms the roof of this part of the mine. Some of the "spars" extend part way through the coal bed and others completely through it. Some are very irregular and contain angular blocks of coal embedded in the sand and gravel. In some places the filling is obviously connected with a fault where the coal bed has been offset a foot or more. St. John believes that these masses are due to infiltrations into shrinkage cavities, but it is difficult to understand how a mass like that shown in figure 8, *D* (p. 60), consisting of conglomeratic sandstone and containing detached irregular blocks of coal could have been formed in this way. The phenomena are obviously connected in some manner with the deposition of the overlying conglomerate, which was laid down on a previously eroded surface. The occurrence of the sandstone masses in fault planes suggests that the

cavities are in some way connected with rock movements, and the fact that the faults do not affect the overlying conglomerate suggests that the movement took place before the conglomerate consolidated, if not before it was laid down.

The floor of the mine is a more or less sandy black shale, carbonaceous and hard, and is well adapted to mining, for it is relatively even in most places and shows little tendency to creep or heave. However, in mine No. 6 the floor is uneven and billowy, the crest of the ridges rising 2 feet or more above the general level. (See fig. 8.)

In mine No. 4 the floor shale, where it has been penetrated to the underlying Trinidad sandstone, is about 5 feet thick. In mine No. 1, at locality 173, it is something more than 17 feet thick and contains beds of sandstone and one bed of coal 1 foot thick. Still farther to the north, in the north fork of Willow Canyon, the underlying shale is 20 feet thick. Apparently the top of the Trinidad sandstone was uneven and the hollows were filled with clay and sand prior to the formation of the coal bed.

CHARACTER, ANALYSES, AND TESTS OF THE COAL.

The coal from the Willow mine is a black, relatively hard and tough, bituminous coal. It does not crumble easily on exposure to the weather and stands shipment without serious deterioration. It is vitreous to dull in luster and of seamy or banded texture caused by seams of vitreous coal alternating with seams of dull porous coal or mineral charcoal. It differs greatly in purity from place to place, being bony and shaly in some places and relatively free from bone and bedded impurities in other places. Some of the shale parts readily from the coal, but much of the bone is not separable by ordinary methods of mining.

The chemical composition of the coal from the Willow mine is shown by the analyses that follow and also by those given in the table of analyses (pp. 240–246). Many tests of this coal were made before the present investigation was undertaken, some during the preliminary development of the mine and others since the mine became productive. Before the mine was opened, six samples of the coal were collected for analysis by employees of the coal company from a prospect opening in Willow Canyon, where the coal occurs in two benches 3 feet and 4 feet 11 inches thick, respectively, separated by 1 foot 3 inches of shale. They were sent for analysis to William B. Potter, of the St. Louis Smelting & Testing Works, who gave the following results:

Analyses of coal from the Willow district.

[Wm. B. Potter, analyst.]

	1	2	3	4	5	6
Moisture	5.39	5.63	3.61	2.31	2.13	1.53
Volatile matter	33.64	33.55	35.24	31.81	34.12	39.50
Fixed carbon	55.58	51.71	54.77	48.22	49.52	47.93
Sulphur	.66	.63	.66	.73	.82	.62
Ash	6.73	8.48	5.72	16.93	13.11	10.42
British thermal units	11,390	11,287	12,692	11,481	12,179	12,820

1. Top of upper bench.
2. Upper part of upper bench.
3. Lower part of upper bench.
4. Top of lower bench.
5. Middle of lower bench.
6. Lower 9 inches of lower bench.

These samples were taken near the surface, and the coal was more or less weathered. Fresh samples taken since the mine was developed show a higher heating value—13,530 British thermal units—and also prove that the two benches are so nearly alike chemically that the bed may be regarded as a unit so far as quality of coal is concerned. When these tests were made it was supposed that the coal of the lower bench only would produce coke, but coal from both benches is now used in the coke ovens.

Coke produced from coal taken from the lower bench, including Nos. 4 and 5 above, was analyzed as follows:

Analysis of coke from Willow district.

[W. B. Potter, analyst.]

Moisture	0.18
Volatile matter	.65
Fixed carbon	75.58
Sulphur	.49
Ash	23.10

Coal was collected from the Willow mine under the supervision of J. S. Burrows for the several tests made at the United States Geological Survey fuel-testing plant. The results of these tests have been reported as follows:[7]

New Mexico No. 3A consisted of run-of-mine coal used in steaming test 396 and producer-gas test 121. New Mexico No. 3B consisted of 10 tons of lump and was used in steaming tests 389 and 391; also, together with equal portions of washed New Mexico No. 4B and No. 5, in coking test 152 and cupola tests 98 and 130. New Mexico No. 3C consisted of 40 tons of slack and was used in steaming test 392 (on washed coal), washing test 168, and coking tests 148 and 149 (on washed coal). At this mine coal that passes through a ¾-inch screen is called "slack," and that passing over the ¾-inch screen is graded as lump.

Two mine samples were taken for chemical analysis. Sample 3221 was taken in room 36, off right entry 4, 2,000 feet northwest of the drift mouth, and sample 3222 was taken in left entry 1, 3,000 feet

[7] Report of the United States fuel-testing plant at St. Louis, Mo., January 1, 1906, to June 30, 1907: U. S. Geol. Survey Bull. 332, pp. 177-180, 1908.

from the drift mouth. The sections of the coal bed where these sections were cut are as follows:

Sections of coal bed in Willow mine.

No. 3221.

	Ft.	in.
Coal (sampled)		11
Shale		1¼
Coal		2
Shale		1
Coal		1½
Shale		1¼
Coal (sampled)	1	5
Coal, bony		7½
Coal (sampled)	2	6
Shale (sampled)		¼
Coal (sampled)		10
	6	10¾

No. 3222.

	Ft.	in.
Coal (sampled)		5
Bone (sampled)		¼
Coal (sampled)	1	1
Bone (sampled)		1
Coal (sampled)		9
Coal, bony		7
Coal (sampled)	1	4
Bone		2
Coal (sampled)		5
Bone		2½
Coal (sampled)	1	11
	6	11¾

Chemical analyses of New Mexico No. 3.

	Mine samples.		Car samples.			Steaming tests.[a]			
			A	C	B	A	B		C
						396	389	391	392
Laboratory No.	3221	3222	3295	3307	3308				
Air-drying loss	1.00	2.00	2.00	3.00	1.40				
Proximate:									
Moisture	2.50	3.48	3.45	4.36	2.75	2.82	3.01	2.47	4.77
Volatile matter	35.47	23.02	32.00	32.21	33.19	32.72	32.61	32.99	33.10
Fixed carbon	52.90	50.58	47.82	47.51	48.54	47.56	47.05	47.63	49.90
Ash	9.13	12.92	16.67	15.92	15.52	16.90	17.33	16.91	12.23
Sulphur	.72	.64	.73	.83	.64	.72	.72	.67	.71
Ultimate:									
Hydrogen			4.95	4.79	4.84	4.72	4.55	4.58	4.83
Carbon			66.19	65.96	67.70	68.45	67.93	68.43	72.14
Nitrogen			1.23	1.18	1.18	1.28	1.19	1.19	1.26
Oxygen			10.23	11.32	10.12	7.42	7.72	7.77	8.17
Ash						17.39	17.87	17.34	12.85
Sulphur						.74	.74	.69	.75
Calorific value (as received):									
Determined — calories	7,293		6,607	6,618	6,759				
Determined — B. t. u.	13,127		11,893	11,912	12,166				
Calculated from ultimate analysis — calories			6,629	6,509	6,715				
Calculated from ultimate analysis — B. t. u.			11,932	11,716	12,087				

[a] Proximate analysis of fuel as fired; ultimate analysis of dry fuel figured from car sample.

Steaming tests of New Mexico No. 3.

	A	B		C
	Test 396.	Test 389.	Test 391.	Test 392 (w.).
Size as shipped	run of mine.	lump.	lump.	slack.
Size as used:				
Over 1 inch ... per cent..	14.8	30.6	34.5	5.6
½ inch to 1 inch ... do....	23.2	27.1	27.9	27.9
¼ inch to ½ inch ... do....	22.2	18.3	16.8	31.3
Under ¼ inch ... do....	39.8	24.0	20.8	35.2
Duration of test ... hours..	10.0	10.0	10.0	9.37
Heating value of coal ... B. t. u. per pound of dry coal..	12,301	12,213	12,301	13,059
Force of draft:				
Under stack damper ... inch water..	0.60	0.54	0.57	0.64
Above fire ... do....	.22	.18	.21	.22
Furnace temperature ... °F..	2,333	2,225	2,432	2,420
Dry coal used per square foot of grate surface per hour .. pounds..	23.48	20.91	23.82	24.56
Equivalent water evaporated per square foot of water-heat-surface per hour ... pounds..	3.86	3.51	4.09	4.25
Percentage of rated horsepower of boiler developed	108.2	98.5	114.8	119.2
Water apparently evaporated per pound of coal as fired . pounds..	6.84	7.02	7.18	7.08
Water evaporated from and at 212 °F.:				
Per pound of coal as fired ... do....	8.00	8.16	8.40	8.26
Per pound of dry coal ... do....	8.23	8.42	8.61	8.68
Per pound of combustible ... do....	10.36	10.54	10.66	10.16
Efficiency of boiler, including grate ... per cent..	64.61	66.58	67.59	64.19
Coal as fired:				
Per indicated horsepower hour ... pounds..	3.54	3.46	3.37	3.42
Per electrical horsepower hour ... do....	4.36	4.28	4.16	4.23
Dry coal:				
Per indicated horsepower hour ... do....	3.44	3.36	3.28	3.26
Per electrical horsepower hour ... do....	4.24	4.15	4.06	4.02

Producer-gas tests of New Mexico No. 3 A (run of mine).

Test 121.—Duration of test, 50 hours; average electrical horsepower, 198.4; average B. t. u. per cubic foot of gas, 155.1; total coal fired, 12,850 pounds.

	Coal as fired.	Dry coal.	Combustible.
COAL CONSUMED IN PRODUCER PER HORSEPOWER HOUR (POUNDS).			
Per electrical horsepower:			
Commercially available	1.37	1.32	1.05
Developed at switch board	1.30	1.25	.99
Per brake horsepower:			
Commercially available	1.17	1.12	.90
Developed at engine	1.10	1.06	.85
EQUIVALENT USED BY PRODUCER PLANT (POUNDS).			
Per electrical horsepower:			
Commercially available	1.47	1.42	1.13
Developed at switch board	1.39	1.34	1.07
Per brake horsepower:			
Commercially available	1.25	1.21	.96
Developed at engine	1.18	1.14	.91

Analyses of coal used in producer-gas tests.

Coal.

Moisture	3.62
Volatile matter	31.56
Fixed carbon	45.19
Ash	19.63
Sulphur	.72

Gas by volume.

Carbon dioxide (CO_2)	9.2
Carbon monoxide (CO)	20.5
Hydrogen (H_2)	14.5
Methane (CH_4)	2.0
Nitrogen (N_2)	53.4
Ethylene (C_2H_4)	.4

Washing and coking tests of New Mexico coal No. 3.

Washing test 168 (coal C, slack).—Jig used, Stewart. Raw coal, 43,000 pounds; washed coal, 38,000 pounds; refuse 5,000 pounds.

Coking tests.

	3 C (slack).		3 B (lump), 4 B (slack), and 5 (run of mine).
	Test 148 (raw).	Test 149 (washed).	Test 152 (washed).
Size as used	finely crushed.	finely crushed.	finely crushed.
Duration of test ....hours	52	48	48
Coal charged ....pounds	12,120	11,710	12,000
Coke produced ...do	7,655	7,233	7,596
Coke produced ...per cent	63.16	61.77	63.30
Breeze produced ...pounds	410	360	328
Breeze produced ...per cent	3.38	3.07	2.73
Total yield ....do	66.54	64.84	66.03

Remarks.—Test 148: Light gray and silvery; good heavy coke; ash high. Test 149 Light gray and silvery; good heavy coke; ash reduced by washing, but still high. Test 152: Light gray and silvery; good, strong, heavy coke; good ring, breakage, and cell structure.

Analyses.

	Washing test 168.		Coking test 148.		Coking test 149.		Coking test 152.	
	Raw coal.	Washed coal.	Coal.	Coke.	Coal.	Coke.	Coal.	Coke.
Moisture	4.36	6.01	3.68	0.76	5.74	0.88	5.13	0.69
Volatile matter	32.21	....	33.06	.67	33.02	1.51	33.88	1.48
Fixed carbon	47.51	....	48.94	78.14	48.99	80.42	50.06	82.18
Ash	15.92	12.43	14.32	20.43	12.25	17.19	10.93	15.65
Sulphur	.83	.71	.78	.71	.72	.65	.69	.63

Cupola tests of coke made from New Mexico Nos. 3 B, 4 B, and 5 coal (washed).

Charge.

Cupola test No.	Coke.[a] Test No.	Coke. Specific gravity.	Coke. Ratio iron to coke.	Fluidity strip full.	Materials.	Divisions of charge. 1.	2.	3.	4.	5.	Total.
				Per ct.		*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
98	152	1.91	7	99.9	Coke.........	210	55	55	55	55	430
					Pig iron......	630	405	405	405	405	2,250
					Scrap.........	210	135	135	135	135	750
130	152	1.91	7	99.9	Coke.........	200	58	58	57	57	430
					Pig iron......	600	413	413	412	412	2,250
					Scrap.........	200	138	138	137	137	750

[a] Phosphorus in coke, 0.0348 per cent.

Record of melt.

Cupola test No.	Blast pressure. On at—	Blast pressure. Maximum.	Iron running in—	Weght of iron. Poured.	Weght of iron. Additional melted.	Weght of iron. Total.	Melting. Time.	Melting. Rate per hour.	Melting. Ratio iron to coke.	Loss.	Recovered. Iron.	Recovered. Coke.
		Oz.	*Min.*	*Lbs.*	*Lbs.*	*Lbs.*	*Min.*	*Lbs.*		*Per ct.*	*Lbs.*	*Lbs.*
98	1.48 p. m....	7	11	1,162	325	1,487	29	3,076	4.31	7.50	1,288	85
130	3.18 p. m....	7	10	1,778	252	2,030	28	4,511	6.51	7.03	759	118

Ladle record.

Ladle No.	Test 98. Pounds.	Test 98. Time (p. m.).	Test 130. Pounds.	Test 130. Time (p. m.).	Ladle No.	Test 98. Pounds.	Test 98. Time (p. m.).	Test 130. Pounds.	Test 130. Time (p. m.).
1.........	83	2.07	94	3.34	13.........	55	2.24	94	3.45
2.........	86	2.07½	52	3.34½	14.........	64	2.24½	84	3.45½
3.........	39	2.08	97	3.38	15.........	53	2.25	82	3.46
4.........	78	2.15	88	3.38½	16.........	68	2.27	24	3.47
5.........	79	2.15½	79	3.39	17.........	42	2.27½	86	3.49½
6.........	86	2.16	109	3.39½	18.........	66	2.28	99	3.50
7.........	58	2.18	83	3.40½	19.........	....	....	84	3.51
8.........	66	2.18½	82	3.41	20.........	....	....	64	3.51½
9.........	70	2.19	91	3.42	21.........	....	....	86	3.53½
10.........	52	2.21	95	3.42½	22.........	....	....	25	3.54
11.........	61	2.22	75	3.43½	23.........	....	....	57	3.55
12.........	56	2.22½	48	3.44					

Remarks.—Test 98: Iron very hot and fluid. Large quantities of slag closed up tuyeres after sixteenth ladle.

The coal in different parts of the mine differs considerably in its burning qualities. That from the main mine is used for steaming coal, principally on railroad locomotives, but that from No. 5 mine is relatively free from bone and is sold almost entirely for domestic use. It does not clinker badly nor adhere to the grate but sticks to brick. It can be used, though not with much success, in the smithing forge. It gives a dense creamy yellow smoke and cokes with emission of tar.

The screenings from the mine are shipped to Gardiner, where they are washed and coked. (See Pl. IX, *A*.) The product is a light-gray coke of silver luster, heavy and strong, and is used successfully in smelters. A comparison of results obtained by tests made on this coal at the United States Geological Survey Fuel Testing Plant with the results of similar tests made on eastern coals indicates that the coal compares favorably with high-grade eastern coking coals.[8]

The Willow coal shows little tendency to slack under ordinary conditions, but the waste from the washer is said to take fire spontaneously because of the moisture constantly supplied to the dump by the addition of wet material. This waste also takes fire more readily after a rainstorm. The coal bed is not greatly disturbed by faults or folds, but several slips of a few feet are reported, and all of them are of the normal type. The greatest displacement observed is 15 feet at a fault in No. 1 mine. (See fig. 7.)

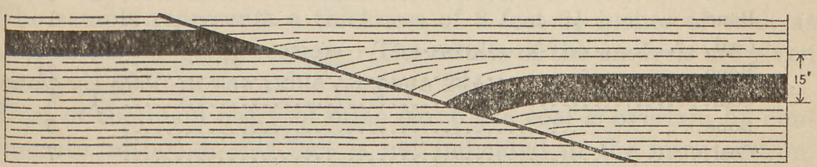


FIGURE 7.—Sketch section of a fault in Willow mine No. 1. The beds shown at the right have dropped 15 feet. Although this is a normal fault the beds of the hanging wall are bent downward.

SECTIONS OF COAL BED MEASURED IN WILLOW MINE.

The coal bed at locality 81 in Castle Canyon, as described on page 31, is 6 feet 1 inch thick and has shale below and conglomerate above it. At the time of the first investigation the workings of the Willow mine had been driven southward to a point a little more than 1,000 feet from this opening in Castle Canyon. In the summer of 1919 the workings had been driven southward and westward around the head of Castle Canyon. The character of the coal bed in the southern extensions is sufficiently indicated by the sections measured at the outcrop to the south. At locality 156 the coal is thinner and the bed more irregular than it is at the outcrop. This condition may be due to local disturbances of the rocks that resulted in the formation of several small faults and the intrusion of the igneous dikes that have been encountered in the mine. The main entry of mine No. 4 cuts four large dikes, and several smaller ones ranging in thickness from 6 inches to 2 feet or more. The coal is coked on either side of the dikes, but seems to be unaffected a few feet from them.

The variations in the thickness and in the character of the coal bed as indicated by measurements made in the mine are shown

[8] Op. cit., pp. 198–199.

graphically in Plate VI. The localities where sections were measured were so chosen as to represent the greatest area possible.

At locality 155, in the southern part of mine No. 4, the part of the bed removed in mining has the appearance indicated by section 155. Farther east the coal is somewhat thicker, on the whole varying from 2 feet 6 inches to 4 feet 5 inches. At locality 156 it is 3 feet 11 inches thick, but this probably represents only the lower bench or the part of the bed below the one shown in section 155. The bed thickens toward the north and is 6 feet 8½ inches thick at locality 157. Farther to the north, at locality 158, it becomes bony near the top, and still farther, at localities 159 and 160, the coal contains a large percentage of bone. At locality 160 the following section was measured:

Section of coal bed at locality 160, in western part of Willow mine.

	Ft.	in.
Coal	1	5
Bone		1
Coal		3½
Bone		2½
Coal	1	5
Bone		5
Coal		7
Bone		2½
Coal	1	2½
	5	10

It is not known whether the sections represent the same part or different parts of the bed, as they include only the portions mined. However, the coal in this part of the mine was found to be too irregular and dirty for profitable mining, and the workings were abandoned.

Farther east, near the main entry of mine No. 4, the coal is thicker and cleaner than at the localities just described. It is reported to be 5 feet thick at locality 161 and 4 feet 3½ inches thick at locality 162. South of these localities the bed is somewhat disturbed by small faults and dikes, and still farther to the south the bed is irregular in thickness. At locality 163 the coal is 4 feet thick. A drill hole put down near locality 163 penetrated 186 feet of rock that overlies the main coal bed, but only one thin bed of coal was found. This bed is 5½ inches thick and lies 41 feet above the top of the main coal.

In the entry connecting mines No. 4 and No. 6 the coal is relatively thick, there being 6 feet 5 inches of clean coal at locality 164, but farther to the southeast, at localities 165 and 166, it becomes bony, as shown in the sections in Plate VI. The lower part of the bed here consists of clean coal and the bone in the upper part of section 166 may occur above the clean coal shown in neighboring sections.

A little to the northeast of locality 166 K. M. Way [9] measured a section of the coal bed in room 5 off the third left entry, 300 feet south of the mine mouth in mine No. 6, and collected a sample of the coal for analysis on December 6, 1908. The section is as follows:

Section of coal bed in room 5, off third left entry of Willow mine No. 6.

	Ft.	in.
Sandstone (the conglomeratic sandstone of this bulletin).		
Coal, bony		3¼
Coal (sampled)	3	3¾
Shale, hard		1¼
Coal (sampled)	1	4
Coal, bony	1	2
Coal (sampled)	1	3½
Coal, bony		⅜
Coal (sampled)	2	4
Shale.		
	9	10⅜

The sample represents a thickness of 8 feet 3¼ inches of coal, as shown in the foregoing section. The results of the analysis are given as analysis 6930 in the table on page 241.

East of the main entry of mine No. 6 the coal is overlain by conglomerate, although this fact is not indicated in the mine section. At locality 167, 6 feet 8½ inches of clean coal is reported, but still farther to the east, at locality 168, a layer of bony coal occurs in the upper part of the bed. This bony layer seems to be merely local, for clean coal occurs still farther east and is 6 feet thick at locality 169. This thickness apparently represents only the main bench of coal. St. John reports 5 inches of coal below this bench and separated from it by 7 inches of shale at the outcrop north of locality 169. At locality 170 the main bench is 5 feet 8½ inches thick, and still farther south it thins to 2 feet 6 inches, where operations were abandoned. In this part of the mine the thickness of the coal is variable because the bed was eroded prior to the deposition of the overlying conglomerate, and south of locality 140 the conglomerate wholly replaces the coal at the outcrop.

The upper surface of the coal bed is very irregular in some places. Gravel-filled depressions 2 feet or more in depth were observed. There are also many dikelike bodies or "spars" of sandstone and conglomerate within the coal bed, most of which are connected with the conglomeratic sandstone above. The relations of several of these bodies to the coal bed are shown in figure 8. The drawings were made from sketches and measurements made in the mine. Some of the bodies are more or less regular, like the one illustrated in *A* in this figure, and have the general appearance of a dike. Others

[9] Lord, N. W., and others, Analyses of coal: Bur. Mines Bull. 22, p. 644, 1913.

extend only part way through the coal. Some are very irregular and complicated in design and range in thickness from a fraction of an inch to 4 or 5 feet. Some of the larger masses are conglomeratic.

As illustrated in *C* (fig. 8) masses of the conglomeratic sandstone have cut through the shale that overlies the coal and well into the coal bed or completely through it. In several places detached masses of coal are included in the sandstone, as shown in *D* of this figure.

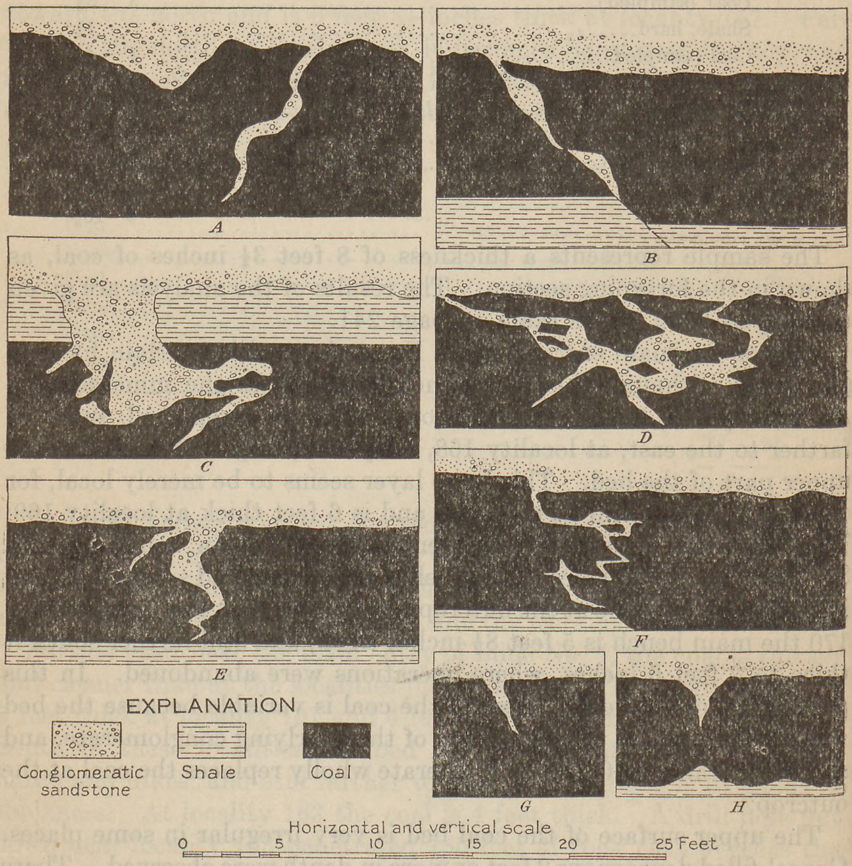


FIGURE 8.—Inclusions of sandstone and conglomerate in the Raton coal bed in Willow mine. Some of these inclusions are relatively regular in form and occur in fault planes; others are very irregular. Some contain angular fragments of coal and pebbles like those of the overlying conglomerate.

These masses have rough surfaces and sharp, angular edges as if they had been torn from previously consolidated coal. In two places examined the sandy inclusions were associated with slight displacements by faulting. In one place, shown in *F*, the displacement was in evidence at both the upper and lower surface of the coal bed. In another place, shown in *B*, the lower surface indicated a displacement of a foot or more, but the offset at the upper surface had evidently

been eroded away. In no place was the faulting observed to extend to the overlying conglomerate. The origin of these dikelike bodies in the coal is not understood, but all things considered it is obvious that they are associated in some way with the deposition of the conglomerate. As the conglomerate was deposited upon an eroded surface, the cavities may have been open fissures such as are sometimes found in rocks exposed at the surface, and these fissures may have been filled at the time the conglomerate was laid down. Furthermore, the faults are traceable through the coal and the overlying shale but not into the conglomerate, which points to the inference that the cavities may possibly be due to rock movements prior to the consolidation of the conglomerate. The angularity of the blocks of coal included in the masses of sandstone seems to prove that the bed from which they were derived had passed beyond the stage of peat, or, in other words, that it was a bed of consolidated coal at the time the sand and gravel found its way into the cavities.

At locality 143, in mine No. 2, between Spring Gulch Canyon and the main canyon of Willow Creek, the coal is 13 feet thick, as previously described, and the basal conglomerate of the Raton formation rests upon it. However, this excellent bed becomes variable in thickness and character toward the west, and a parting of shale separates it into two benches. It has been reported that the lower bench pinches out in that direction and that the upper bench does not thicken to any notable extent. However reports differ, and there are some reasons for believing that the upper bench was eroded away in some places during the period of post-Vermejo erosion.

At locality 171 the coal in the mine is reported as only 2 feet 6 inches thick, but a drill hole started in Willow Canyon, about 2,000 feet upstream from the outcrop of the coal, penetrated the coal bed near locality 171, where the coal is 4 feet 6 inches thick with sandstone above and below it. The upper sandstone is 15 feet thick and is probably the conglomerate described in this bulletin. The relations revealed by this drill prospect suggest that the conglomeratic sandstone replaced the upper part of the coal bed. Unfortunately this question can not now be answered without access to abandoned parts of the mine. Still further confusion arises from a report that about 1,500 feet farther north in the mine both benches of coal are present.

At locality 172 the lower bench has been opened in the mine workings but is too thin for economic operation and the upper bench contains coal that is too bony for profitable mining. The character of this upper bench is shown in section 172 in Plate VI. Because of the unsatisfactory character of the bed in this region the mine workings were not driven westward beyond these localities.

Farther north the workings of mine No. 1 were driven in on the lower bench of coal, but at one point, locality 173, both benches are exposed in a rock cut, where the following section was measured. The lowest bench of coal, 1 foot thick, was not found at neighboring localities. The 4-foot bench is the lowest coal mined.

Section of coal bed at locality 173, in Willow mine No. 1.

	Ft.	in.
Sandstone.		
Coal	3	
Shale	6	8
Coal		3½
Coal, bony		2
Coal		8
Coal, bony		10
Coal	1	2
Coal, bony		7
Coal	4	
Shale with thin seams of coal	1	5
Coal	1	
Shale and sandstone in alternating layers	15+	
	34+	

At the western extremity of the mine the coal of the lower bench is bony and mining operations on it were suspended. Its character is indicated by section 174 on Plate VI. That this is the lower bench and that the upper bench is not present near this locality was proved by the drill. A hole started in Spring Gulch penetrated the bed close to locality 174 and gave the results shown below. The 33-foot sandstone of the record is obviously the conglomeratic sandstone which elsewhere replaces a part or all of the coal bed, and it seems evident that the upper bench of coal and its underlying shale, as found near locality 173, were eroded away before the sandstone was formed. The record is as follows:

Rocks penetrated by the drill near locality 174, at the horizon of the main coal in Spring Gulch.

	Ft.	in.
Sandstone	33	
Shale		8
Coal	3	2
Shale		2
Coal with streaks of shale	2	10
Coal	3	4
Shale		10
Coal, shaly		6
Shale		5+
	44	11+

At the western extremity of the northernmost entry of this mine, at locality 175, an upper thin bed is reported to occur 15 feet above

the coal exposed in the mine, but the thickness of this upper bed was not ascertained. These are believed to be the two benches just described at locality 173 and the same benches as those that come together near the mouth of mine No. 1 to form the 13-foot bed of coal. The section of the lower bed at locality 175 is shown in Plate VI.

About 300 feet east of this locality a normal fault crosses the entry from northeast to southwest with a downthrow of 15 feet to the northwest. This fault is peculiar in that the beds above the break are bent downward instead of upward as would naturally be expected for a normal fault. (See fig. 7, p. 57.) Still farther to the east, at locality 176, the coal in the mined portion of the bed is somewhat bony, as shown in section 176 in Plate VI. East of the main entry the coal was mined out long ago, and no record of its thickness or the character of the bed was obtained.

Near the northern extremity of mine No. 1 the coal has been disturbed by rock movements and by the intrusion of igneous rock at about the horizon of the coal. The bed is warped and faulted and coke was found in several places. The condition of the bed north of the mine workings has been tested in two places by the drill. One hole was put down in the east fork of Willow Canyon about 1,150 feet above the point where the outcrop of the coal crosses the stream. The exact location was not learned. The record of this hole is as follows:

Record of rocks penetrated by the drill northeast of locality 176, in east fork of Willow Canyon.

	Ft.	in.
Sandstone	63	
Coal	2	10
Coal, shaly		9
Coal	2	7
Shale		1
Coal	1	7
Shale		1
Coal, shaly		6
Shale		2
Coal	1	11½
Coke	1	11½
	75	6

About 2,000 feet farther up the canyon the coal is all metamorphosed, as is indicated by the record given on page 64. The hole drilled here is 262 feet 5½ inches deep, and the bottom of the coal bed was about 256 feet below the surface. The coal bed gave the following section:

Section of coal bed penetrated by the drill in east fork of Willow Canyon.

	Ft.	in.
Sandstone	11	
Shale		6½
Coke	5	10½
Shale		6
Coke	1	2
Coal, shaly, baked	1	2
Shale, baked	2	
Igneous rock		10
Shale, baked	2	6
Shale, sandy		10
Sandstone		4½+
	26	9½+

These records, when compared with the section described from the outcrop in this canyon, indicate that a large body of coal lies north of mine No. 1 but that it has been practically destroyed by the intrusion into it of igneous rock.

The character of the coal bed west of mine No. 1 was also tested by the drill. A hole was put down in Willow Canyon at locality AA, about a mile from the place where the outcrop of the coal bed crosses the stream. The drill penetrated the sandstone below the coal bed to a considerable depth, and it is evident that at this locality there is only one bench of coal in place of the two described in mine No. 1. The 40-foot sandstone of the record is probably the conglomeratic sandstone that is now known to lie unconformably on the coal-bearing rocks in the Willow district, and the rocks below the main coal bed doubtless represent the Trinidad sandstone and the top of the Pierre shale. The record is as follows:

Rocks penetrated by the drill at locality AA, in Willow Canyon.

	Ft.	in.
Surface soil	11	
Sandstone	80	6
Shale	1	
Coal		6
Shale	5	
Sandstone	28	
Shale	63	
Sandstone	29	
Shale	4	
Sandstone	2	
Shale	8	
Sandstone	40	
Coal	3	5
Shale	2	7
Sandstone	35	
Shale	4	
Sandstone	75	
Shale	15	6
	407	6

At locality BB, about 3,500 feet farther up the canyon, another hole was drilled and here the main bed of coal is 5 feet thick and has shale above and below it. The 32-foot sandstone probably represents the conglomeratic sandstone of other sections. The record is as follows:

Rocks penetrated by the drill at locality BB, in Willow Canyon.

	Feet.
Surface soil	20
Shale	20
Sandstone	17
Sandstone and shale	62
Sandstone	29
Shale	13
Sandstone	10
Shale	9
Sandstone	24
Shale and sandstone	83
Sandstone	18
Shale	3
Sandstone	2
Shale	13
Sandstone	25
Shale	56
Sandstone	5
Shale	9
Coal	1
Shale	51
Sandstone	11
Shale	6
Sandstone	32
Shale	3
Coal	5
Shale	5
Sandstone	2
	534

In the western part of mine No. 5 the coal is greatly disturbed by intrusions of igneous rock, but owing to the excellence of the coal some development work is continued in spite of discouraging prospects. At locality 177 the coal bed is 5 feet 8 inches in thickness and has conglomerate above it and shale below. South of the western end of the main entry the coal is burned out near the surface. The burning seems to have been very recent, if indeed it is not still in progress, for the rocks are perceptibly warmer in this part of the mine than they are in other parts, and sulphurous fumes are still being given off.

In the main entry of mine No. 5 the coal ranges in thickness from less than 5 feet to 11 feet or more. At locality 178 it is 5 feet 3½ inches thick and has 1 inch of bone, as shown in the section, Plate VI.

A little farther north, in the main entry of mine No. 5, near the point where the third left entry is turned from the main entry, the writer collected samples of coal for analysis and measured the following section:

Section of coal bed measured at locality 179, near junction of third left and main entries in Willow mine No. 5.

	Ft.	in.
Conglomerate.		
Coal (analysis 6417, p. 241)	1	3
Bone		½
Coal (analysis 6417)		6
Coal, bony		4
Coal (analysis 6417)	3	4
Coal, bony		10
Coal (analysis 6418, p. 241)		1½
Shale		3
Coal (analysis 6418)	4	5
Shale.		
	11	1

The samples for analysis were collected on August 25, 1908. The coal in the upper part of the bed was supposed to differ somewhat in quality from that of the lower part and for this reason two samples were taken, one (No. 6417) representing the three upper benches and the other (No. 6418) the lower two benches.

Another sample of the coal from this mine was collected for analysis by K. M. Way on December 6, 1908, at a point 500 feet west of the mouth of mine No. 5, in the crosscut between the third and fourth entries near room 6. The sample represents 8 feet 11½ inches of coal, as indicated by the following section, which was measured at the point where the sample was taken:

Section of coal bed in crosscut between third and fourth entries, near room 6 in Willow mine No. 5.

	Ft.	in.
Sandstone.		
Coal (sampled)	3	10
Shale		1
Coal (sampled)		5
Coal, bony		7
Coal (sampled)		9
Coal, bony		2½
Coal (sampled)	1	7¼
Shale		¼
Coal (sampled)	2	4
Shale.		
	9	10

The chemical character of the coal is shown by analysis 6931 in the table on page 241.

North of locality 179 the coal is so badly broken and otherwise affected by intrusions of igneous rock that little of it has been mined, but east of this locality the coal bed maintains considerable thickness,

being 8 feet thick in the main entry of mine No. 7 and 10 feet thick at locality 180. Still farther east, as previously described, the bed thins and becomes somewhat shaly on the outcrop at locality 149.

MINING DEVELOPMENT.

Mines Nos. 1, 2, 4, and 6 are connected by electric tramways with the main tipple, and mines Nos. 5 and 7 are connected by a gravity incline with an independent tipple. The mines are operated on the double-entry room-and-pillar system. The main entries are driven in the direction of the strike of the beds and the cross entries in the direction of the dip, which is very slight. Where the conglomerate forms the roof of the mine no timbering is required. Where the roof is shale the gangways are timbered with props and cross-bars and the rooms with props and caps.

The main entries of the mine are lighted by electricity, but open lights are used in the rooms. Ventilation is accomplished by means of exhaust fans. There is one Cappell fan 13 feet 6 inches in diameter, one Crawford fan 30 inches in diameter, and one high-speed steel plate fan 6 feet in diameter. Little gas has been encountered. The mine is dry in most places, and nowhere does water interfere with mining.

The coal is drilled by hand with breast and post drills and shot from the solid. The powder used is Monobell No. 5 and is handled only by shot firers, who work at night when the miners and other laborers are out of the mine. During the summer of 1913 Goodman short-wall, electrically driven, undercutting chain machines were installed but were not put into operation until after the writer's visit. These machines are adapted for use in rooms of any size.

The loaded cars are gathered and hauled to the main entries by mules and from the mains to the tipple by electric motors. There the coal passes over shaker screens that separate it into lump (about 30 per cent), nut (about 30 per cent), pea (about 20 per cent), and slack (about 20 per cent). The tipple used for mines Nos. 5 and 7 is provided with shaker screen and picking table.

An electric-power plant near the main tipple formerly furnished power for mining operations, but since 1914 power has been obtained by long-distance transmission from an electric plant at Trinidad, Colo.

Gas has given little trouble in the Willow mine, the only place where it is said to be troublesome being in mine No. 1, where the shale parting is well developed between the two benches of coal. The gas is said to come from this shale.

AREA BETWEEN WILLOW AND BLOSSBURG DISTRICTS.

The Raton coal bed has not been found near Red River Peak, and the basal conglomerate of the Raton formation, which overlies this coal in the Willow district, here rests on the Trinidad sandstone, which lies normally below this coal. No coal referable to the Raton bed was found for a distance of about 2 miles west of Red River Peak. This may be due in part to poor exposures, for some of the shale of the Vermejo formation was seen in several places in this distance. Two sections were measured in this region, one at locality 181, about 2 miles west of the peak, and the other half a mile west of the peak, at locality 182. The lower portions of these sections are shown in Plate II. The full section at the latter locality is as follows:

Section of rocks at locality 182, half a mile west of Red River Peak.

[For graphic section of lower part, see Pl. II, p. 12.]

	Feet.
Raton formation:	
Igneous rock (andesite)	15
Sandstone and igneous rock	50
Shale	20
Sandstone, cliff-making	50
Shale, mostly covered	60
Sandstone, white, massive	40
Shale, locally carbonaceous	30
Sandstone, cliff-making	20
Shale, not well exposed	20
Sandstone, conglomeratic, cliff-making	20
Unconformity.	325
Vermejo formation:	
Shale, locally carbonaceous, thickness not determined.	
Trinidad sandstone.	

Still farther to the east and also north of the peak the Vermejo formation was eroded away prior to the deposition of the conglomerate. The rocks from the upper part of the Pierre shale to the top of the peak, a horizon well up in the Raton formation, are well exposed. This shale and the Trinidad sandstone are characteristically developed, but no Vermejo is present. The conglomerate at the base of the Raton formation rests unconformably on the Trinidad sandstone, and the overlying sandstone and shale are not coal-bearing but contain several sheets of intrusive igneous rock.

For half a mile or more north of the peak the conglomerate and the Trinidad sandstone together form a prominent cliff, but the Trinidad sandstone is thinner here than at neighboring localities where the Vermejo formation is present. In other words, the erosion that removed the Vermejo also cut away the upper part of this sandstone. The relations are shown by the following section, which was measured at locality 183, north of the peak.

Section of rocks at locality 183, north of Red River Peak.

[For graphic section see Pl. II, p. 12.]

	Ft.	in.
Raton formation:		
Sandstone, hard, quartzose, conglomeratic	20	
Sandstone, yellowish brown, coarse-grained, poorly consolidated	35	
Shale, sandy, carbonaceous, resembling soil (possibly an old soil representing the base of the Raton formation)		4
Unconformity.		
Trinidad sandstone, soft, friable, greenish in color near the top apparently from surface weathering, grading downward to white massive sandstone; contains *Halymenites major*	35	
Pierre shale.		
	90	4

About a mile northwest of locality 183 the Trinidad sandstone regains its normal thickness and the Vermejo beds again make their appearance. These beds thicken toward the west, but no coal was found for a considerable distance along the outcrop in the south wall of Cottonwood Canyon. The sequence of the rocks at locality 184 is shown by the following section:

Section of rocks at locality 184, in Cottonwood Canyon.

[For graphic section see Pl. II, p. 12.]

	Feet.
Raton formation:	
Igneous rock (diabase)	30
Igneous rock (basalt)	20
Shale, not well exposed	40
Shale, carbonaceous, with thin beds of coal	4
Shale, partly covered	20
Sandstone, cliff-making, conglomeratic at base	15
Unconformity.	
Vermejo formation:	
Shale, carbonaceous	20
Sandstone, rusty	3
Shale, carbonaceous	2
Trinidad sandstone.	
	154

In Cottonwood Canyon, west of locality 184, the rocks of the Vermejo formation were seen at many places, but they are irregular in thickness, much disturbed by the intrusion of igneous rock, and coal is not invariably present in them. A coal bed 2 feet thick, overlain by 20 feet of conglomeratic sandstone, was found near the main fork of Cottonwood Canyon. Half a mile farther west in the north fork of the Canyon coke and graphite resulting from the metamorphosis of the coal is overlain by 15 feet of conglomerate. Throughout a large area adjoining Cottonwood Canyon the main coal has been transformed to graphite by intrusions of igneous rock. Half a mile or more above the fork of the canyon, where the basal conglomerate of the Raton formation lies across the eroded edges of the Vermejo, a

well-defined angular unconformity is exposed. At one end of the exposure the conglomerate lies on the sandstone which is shown by the presence of the characteristic fossil fucoids, *Halymenites major*, to belong to the Trinidad. The conglomerate, about 20 feet thick, lies nearly horizontal, but the underlying beds dip 3° W. The principal coal bed of the Vermejo is here 28 feet above the base of that formation, and this bed, together with a considerable thickness of the sedimentary rocks overlying the coal, was removed by the post-Cretaceous erosion, and the conglomerate was deposited across the truncated edges of the Vermejo beds. The occurrence of the coal 28 feet above the Trinidad sandstone here explains its absence from section 184 (Pl. II), in which the base of the conglomerate is only 25 feet above this sandstone.

In Cottonwood Canyon many sheets of igneous rock, mainly basalt and andesite, have been intruded into the sedimentary rocks at horizons ranging from the Trinidad sandstone well up into the Raton formation. Only the more conspicuous of these sheets are shown on the accompanying map. Much of the igneous material was injected into the coal bed and the less resistant beds of shale near it. This intrusion resulted in small displacements and other disturbances of the sedimentary rocks and in the metamorphosis of the coal. The Raton coal bed generally in Cottonwood Canyon, and also in many places farther north and west in the Canyon of the Canadian, has been changed more or less completely to coke and graphite. The greatest volume of intrusive rock seen by the writer occurs near the main fork of Cottonwood Canyon, and the coal was most completely graphitized here.

At locality 185 there is an old mine opening in the graphite, now abandoned, and the bed near it is well exposed in the walls of the canyon for a considerable distance. The graphite occurs in pockets or irregular masses in igneous rock and is more or less perfectly columnar, as shown in Plate VIII, *A* (p. 48), the columns usually standing normal to the face of the igneous rock. Although both basalt and andesite occur in the intrusive sheet of igneous rock, the most complete graphitization of the coal appears to have been caused by the andesite. The columnar portions are relatively free from impurity, but the noncolumnar parts seem to have been derived from what was originally bony or impure coal.

The graphite mine was opened in 1889 by the Standard Graphite Co. of New York and 250 tons of graphite were shipped from it to Moosic, Pa., and tested in the manufacture of paint. One of the objects of the company was to ascertain whether the graphite could be handled profitably, and careful accounts were kept. According to the statement of one member of the company the graphite could be placed in the bins at Moosic for $17.50 a ton, the greater part of the

cost being shipping charges. At Moosic an additional cost of 90 cents a ton was incurred for grinding it and separating it from some of its impurities by means of air blasts. The refined product contained 80 per cent carbon, the remaining 20 per cent being mostly silica, which was not regarded as objectionable in the manufacture of paint. The tests were satisfactory to the company, and the mill was being taken apart for shipment to Raton when it was destroyed by fire. Nothing has since been done toward developing the graphite.

Analyses of this graphite were made by Andrew S. McCreath, of Harrisburg, Pa., who reported that it contains no sulphur or other material detrimental to its use in the manufacture of paint. To test the effect that weather might have on the paint the graphite was subjected to caustic alkali and to strong acids, including aqua regia, but these produced so little effect that the graphite was pronounced satisfactory as a base for paint.

Two analyses of graphitic coal from this region were published years ago,[10] as follows:

Analyses of graphitic anthracite from the Raton coal field, N. Mex.

	Soft material.	Hard material.
Moisture	1.19	1.22
Volatile matter	4.37	5.45
Fixed carbon	76.07	71.79
Ash	18.37	21.54
Sulphur	.19	.17
Iron		.63
Sulphur required for FeS_2		.72
Sulphur (+ or −)		−.55

The writer collected a sample of the graphite for analysis on September 9, 1908, 160 feet from the mouth of the old opening, at a point where the graphite was about 3 feet thick. In order to obtain a representative sample the weathered material was cleared from the exposed face of the bed. The sample represents the entire thickness of the graphite at this point, and for this reason the analysis shows a greater percentage of impurity than would be found in pieces selected from the best material. The sample was analyzed as coal in the laboratory of the United States Geological Survey, at Pittsburgh, Pa. (now operated by the Bureau of Mines). The results are as follows:

[10] Potter, W. B., The character and composition of the lignite coals of Colorado: Am. Inst. Min. Eng. Trans., vol. 5, pp. 365–375, 1877.

Analyses of graphite from the Raton coal field, N. Mex.

[F. M. Stanton, chemist in charge. Laboratory No., 6521. Air-drying loss, 0. 40 per cent.]

	Material as received.	Air-dried material.	Moisture-free material.	Moisture-free and ash-free material.
Moisture	1. 3	0. 9	....	7. 4
Volatile matter	6. 1	6. 1	6. 2	7. 4
Fixed carbon	76. 1	76. 4	77. 1	92. 6
Ash	16. 5	16. 6	16. 7	....
Sulphur	0. 17	. 17	. 17	. 20

Although the graphite was originally coal, as is clearly indicated by its position at the horizon of the Raton coal bed, its chemical character gives little indication of its origin, and it was somewhat surprising to find 6.1 per cent of "volatile matter" in it, a percentage considerably higher than that carried by some graphites of similar origin. At the writer's request Dr. H. C. Porter made a chemical examination of this volatile matter. A sample consisting of 20 grams of the graphite as received was crushed to rice size and heated 20 minutes in an atmosphere of nitrogen at 930° to 950° C. The volatile matter thus obtained was analyzed, with the following results:

Analyses of volatile matter contained in the graphite of Raton coal field, N. Mex.

		1	2
Total loss (includes moisture 1.31 per cent)	per cent	5. 6	6. 0
Water (includes moisture 1.31 per cent)	do	4. 22	4. 23
Tar		Trace.	Trace.
Gas	liters per kilo	16. 2	15. 0
	cubic feet per ton	520	480
Composition of gas:			
CO_2	per cent	9. 1	....
Illuminants	do	3. 1	....
CO	do	9. 3	....
CH_4	do	19. 5	....
H_2	do	52. 7	....
N_2	do	6. 3	....

In his comments on the results, Dr. Porter says:

This material seems to retain its graphitic streak after heating at a high temperature, which would seem to indicate that it is a true graphite, as does also the fact that it is extremely difficult to burn. The volatile matter * * * is very largely water, which I should say is in the form of combined water or water of crystallization. This is indicated also by the decrepitation on heating.

The volume of intrusive igneous rock diminishes toward the east, but the coal is graphitized for about a mile east of the old mine. At locality 186 the following section of rocks was measured:

Section of rocks at locality 186, in north wall of Cottonwood Canyon.

[For graphic section see Pl. II, p. 12.]

	Feet.
Raton formation:	
Sandstone, cliff-making	25
Shale, carbonaceous, with thin beds of friable sandstone	55
Sandstone, hard, cliff-making	20
Unconformity.	
Vermejo formation:	
Shale	30
Igneous rock containing masses of graphite	2
Shale, black, carbonaceous	2
Shale	6
Trinidad sandstone.	
	140

A similar section was measured on Sugarloaf Mountain and is shown as section 187 in Plate II. For a distance of about 3 miles northwest of Sugarloaf Mountain the rocks at the horizon of the Raton bed are not well exposed in the south wall of Canadian River Canyon, but small outcrops occur in several places where sheets of intrusive igneous rock are associated with coke and graphite. However, at locality 188 in Coal Canyon, which joins Canadian River Canyon from the west, the coal has escaped metamorphosis, and the bed is exposed at the side of the stream, where the following section was measured:

Section of coal bed at locality 188 in Coal Canyon.

	Ft.	in.
Shale containing two beds of coal a few inches thick	10	
Coal	2	11
Shale	1	2
Coal	1	6
Coal, bony		4
Coal		4
Coal, bony	1	
Shale.		
	17	3

Although the extent of the area in Cottonwood Canyon in which the coal has escaped destruction could not be ascertained, it seems to be small, for in the opposite side of the canyon, only a few rods from the point where the section was measured, the coal is metamorphosed by igneous rock, and in many places for a mile or more along the outcrop in Coal and Spencer canyons this rock was observed at or near the horizon of the coal.

The character of the bed was tested by the drill about a mile farther up Coal Canyon, but the exact place is not known. Coke was encountered in place of coal at the horizon of the Raton coal bed, but no igneous rock was penetrated. The record of the drill hole is as follows:

Record of drill hole about a mile southwest of locality 188 in Coal Canyon.

	Ft.	in.
Surface material	14	
Sandstone and shale	11	
Coke		6
Shale	11	6
Coke	1	
Sandstone	4	
Shale	4	6
Coke	1	
Shale	7	6
Trinidad sandstone	89+	
	144+	

Two other drill holes were bored in Coal Canyon at localities CC and DD, but coke and igneous rock were found in both of them at the horizon of the Raton bed (see Pl. XVI, p. 152), from which it seems probable that the area in which the Raton coal is destroyed by igneous intrusions extends at least as far west as the upper part of Coal Canyon. These drill records or holes are described on pages 176–177.

The base of the Raton formation is conglomeratic in Coal Canyon and contains pebbles having a maximum observed diameter of three-eighths of an inch. An attempt was made to trace the line of unconformity between the Vermejo and Raton formations in Canadian River canyon west of the mouth of Coal Canyon, but the sedimentary rocks have been so much disturbed by the intrusion of igneous rock that the attempt was not wholly successful. In several places unconformable relations were noted, but in the absence in some places of a well-developed conglomerate in the beds immediately above the unconformity, it was not satisfactorily demonstrated that these are parts of the general unconformity between the Vermejo and the Raton formations. They may be local unconformities such as are found in many places within the Raton formation. Where the Raton coal bed crosses Canadian River the lowest coal is only 1 foot 6 inches thick, and several thin beds occur at higher horizons, as shown below:

Section of rocks at locality 189, in north wall of Canadian River canyon.

	Ft.	in.
Sandstone.		
Shale	3	
Coal, bony		6
Shale	4	
Coal		3
Shale	3	
Coal	1	
Shale		2
Coal		4

	Ft.	in.
Shale	6	
Coal, bony	1	6
Shale	8	
Sandstone	5	
Shale	4	
Coal	1	
Shale	5	
Sandstone	6	
Coal, bony	3	
Sandstone (probable base of Raton formation)	12±	
Coal	1	6
Shale	2	
Trinidad sandstone.		
	67±	

No conglomeratic rock was found at this locality; hence it is not possible to fix definitely the line of separation between the Vermejo and the Raton formations. It seems probable, however, that the Vermejo practically thins out at this locality and that the 12 foot sandstone of the foregoing section is the base of the Raton formation. If this is the case the higher coal beds may represent the Sugarite zone, which contains a thick bed of coal east of Raton, as described on pages 153–154. This sandstone seems to be traceable eastward in the north wall of Canadian River canyon to a conglomeratic sandstone that is clearly the base of the Raton formation and that lies unconformably on the Vermejo. The conglomerate was found half a mile east of locality 189 and was observed in several places in the canyon near locality 190. From this locality eastward it was traced along the outcrop continuously throughout the Blossburg district.

BLOSSBURG DISTRICT.

LOCATION.

The Blossburg district is here regarded as including all areas of development between Red River and the town of Raton, as well as the area in which the coal has been extensively prospected along the outcrop and by diamond drill back from the outcrop. Parts of the district have been known by different names, such as Dillon Canyon tract, Gardiner area, Dutchman area, Gardiner mine, and Blossburg mine. It contains some of the oldest mines in the Raton coal field and has probably been studied more carefully than any other part of the field. The coal outcrops in the sides of the mesa several hundred feet above the plains and in the canyon sides up to the points where the outcrop crosses the streams; thus the mine mouths can be so chosen as to utilize the force of gravity in hauling the coal from the mine to the tipple.

STRATIGRAPHIC POSITION OF COAL BED.

The coal mined in the Blossburg district is generally known as the Raton coal and is essentially the same as that previously described from the Koehler and Willow districts. It is in the Vermejo formation, which is here only a few feet thick and lies conformably on the Trinidad sandstone, which outcrops immediately above the conspicuous cliff formed by this sandstone. (See Pl. X, *A*, *B*.) Above the Vermejo and lying unconformably on it is the Raton formation, the base of which consists of a conglomeratic sandstone. This sandstone is the northward continuation of the conspicuous conglomerate that occurs above the coal in the Koehler and Willow districts. In the Blossburg district it is much less conspicuous, and in some places it is difficult of recognition. It consists principally of hard coarse-grained quartzose sandstone and contains pebbles in pockets and in lenticular masses that are largest and most numerous near the base. Most of it is massive, but cross-bedding occurs in many places and in others the laminae are irregular and more or less contorted so that the rock weathers to a rough, craggy surface. There are many irregular carbon-stained streaks, apparently caused by the commingling of carbonaceous mud with the sand at the time the sandstone was formed. In Canadian River canyon fragments of soft charcoal were found in it at several places in such form as to suggest that they represent fragments of wood buried in the sand. Small rounded pebbles of coal were also found, and apparently these were derived by erosion from a previously consolidated bed of coal.

The intrusions of igneous rock that destroyed the coal south of Canadian River appear in the north wall of the canyon in some places, but the coal is not wholly destroyed in large areas as it is farther south. The Raton coal in the Blossburg district is not a single bed but, as described in detail below, consists of one to four beds lying close together and perhaps in some places uniting to form a single bed. In spite of the large amount of development work done in this district it does not seem possible at present to determine the relations of these beds to each other and to the neighboring rocks. Some of the mining men believe that the occurrence of two beds at a given locality and only one at a locality near by is due to a "split"; that is, that the two beds of the first locality are parts of the one bed of the second locality separated by a wedge-shaped body of shale. This explanation may be correct for some places but not for all. Another explanation is that the coal beds are lenses superimposed one upon another with their edges overlapping, so that as one bed thins out another bed thickens and takes its place, the two being so nearly at the same horizon that they are interpreted as being the same bed. Even in the mines described below the workings in different

parts may possibly be in different beds, but the passage from one lens to the other is not recorded.

A third explanation for the variability in the number of beds at different localities is the removal of the upper ones by erosion prior to the deposition of the overlying sediments. This explanation certainly holds good for some localities if not for all, and east of the Blossburg district not only do all of the coal beds disappear but no rocks referable to the Vermejo formation have been found. The basal sandstone of the Raton formation there rests unconformably on the Trinidad sandstone.

SECTIONS MEASURED AT THE OUTCROP.

In the north wall of Canadian River canyon, at locality 190, the Vermejo formation is 30 feet thick and contains two beds of coal, but the exposures are so poor that their exact relations were not determined. The coal of the higher bed has been destroyed by an intrusion of igneous rock, but that of the lower bed appears to be in good condition and a prospect entry was run in on it several years ago. The opening was inaccessible at the time of visit and a thickness of only 3 feet of the coal was found at its mouth.

The conglomeratic sandstone at the base of the Raton formation is readily recognized at this locality although it is only a few feet thick. It is hard and quartzose and variable in thickness, color, and constitution. Pebbles one-fourth of an inch or more in diameter occur in it in small pockets. This conglomerate is traceable continously along the outcrop to locality 191 described below, where it forms a prominent cliff. The coal bed can not be traced continuously along the outcrop because of poor exposures. As it occurs in soft shale that is easily eroded it is well exposed in only a few places. Graphite associated with igneous rock was found in several places in the southernmost points of the mesa as far east as locality 197 and throughout this distance the coal appears to have been so nearly destroyed as to be worthless. However, farther to the north the coal is in good condition, as has been proved by the drill. A section measured near locality 191 is as follows:

Section of rocks near locality 191, in north wall of Canadian River canyon.

[For graphic section see Pl. II, p. 12.]

	Feet.
Sandstone, cliff-making.	
Coal and basalt	5±
Shale	35
Sandstone	20
Shale	10
Basalt	3
Shale and sandstone, with thin beds of coal	50
Sandstone, conglomeratic	35

	Feet.
Unconformity.	
Shale, carbonaceous, containing coal, coke, graphite, and igneous rock	20
Sandstone (Trinidad).	
	178±

The intrusions of igneous rock have not so completely destroyed the coal in the canyons farther to the north. St. John gives detailed descriptions of several openings made on the outcrop, which have been used, together with the observations made by the writer, for drawing the sections given in Plate XI. At localities 192 to 197, inclusive, only one bed of coal, probably the lower bed at locality 190, farther to the west, generally occurs about 800 feet northeast of the outcrop of the coal in the canyon. Near locality 194 a diamond drill showed the succession of rocks given below. Here, as at the outcrop, only one bed of coal occurs at the horizon of the Raton bed, and this bed is so much parted with shale as to be of little commercial value. The rocks penetrated by the drill at this locality are as follows:

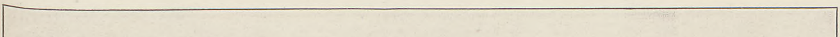
Section of rocks penetrated at locality A, north of Canadian River canyon.

[For graphic section see Pl. XII.]

	Ft.	in.
Surface soil	1	6
Sandstone	20	½
Shale	3	3½
Sandstone	41	6
Shale, sandy	20	3½
Sandstone	51	4
Shale	4	
Coal		3
Sandstone	15	
Coal		2
Sandstone	3	10
Sandstone and shale	27	5
Sandstone	13	6
Shale	5	8
Sandstone	41	9½
Shale	3	
Sandstone	18	8
Shale	2	
Sandstone	13	10½
Shale, carbonaceous	2	2½
Shale	6	10
Sandstone	9	6
Coal	1	
Shale, carbonaceous	6	
Igneous rock	6	7½
Shale and sandstone	20	3½
Sandstone	24	
Shale	20	4
Coal	1	3

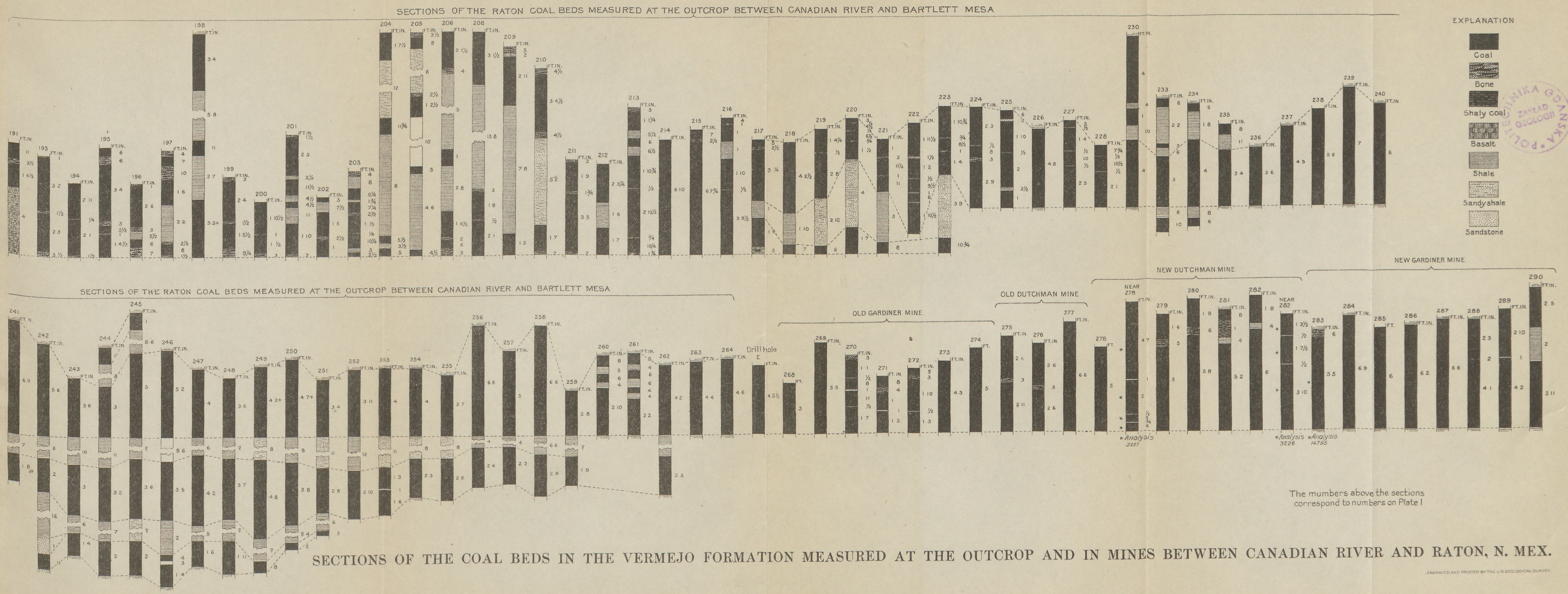
A. NORTH WALL OF CANADIAN CANYON, SHOWING STRATIGRAPHIC RELATIONS OF THE COAL-BEARING ROCKS.

a, Pierre shale; *b*, Trinidad sandstone; *c*, Vermejo formation, containing the Raton coal bed; *d*, cliff-making sandstones of Raton formation.



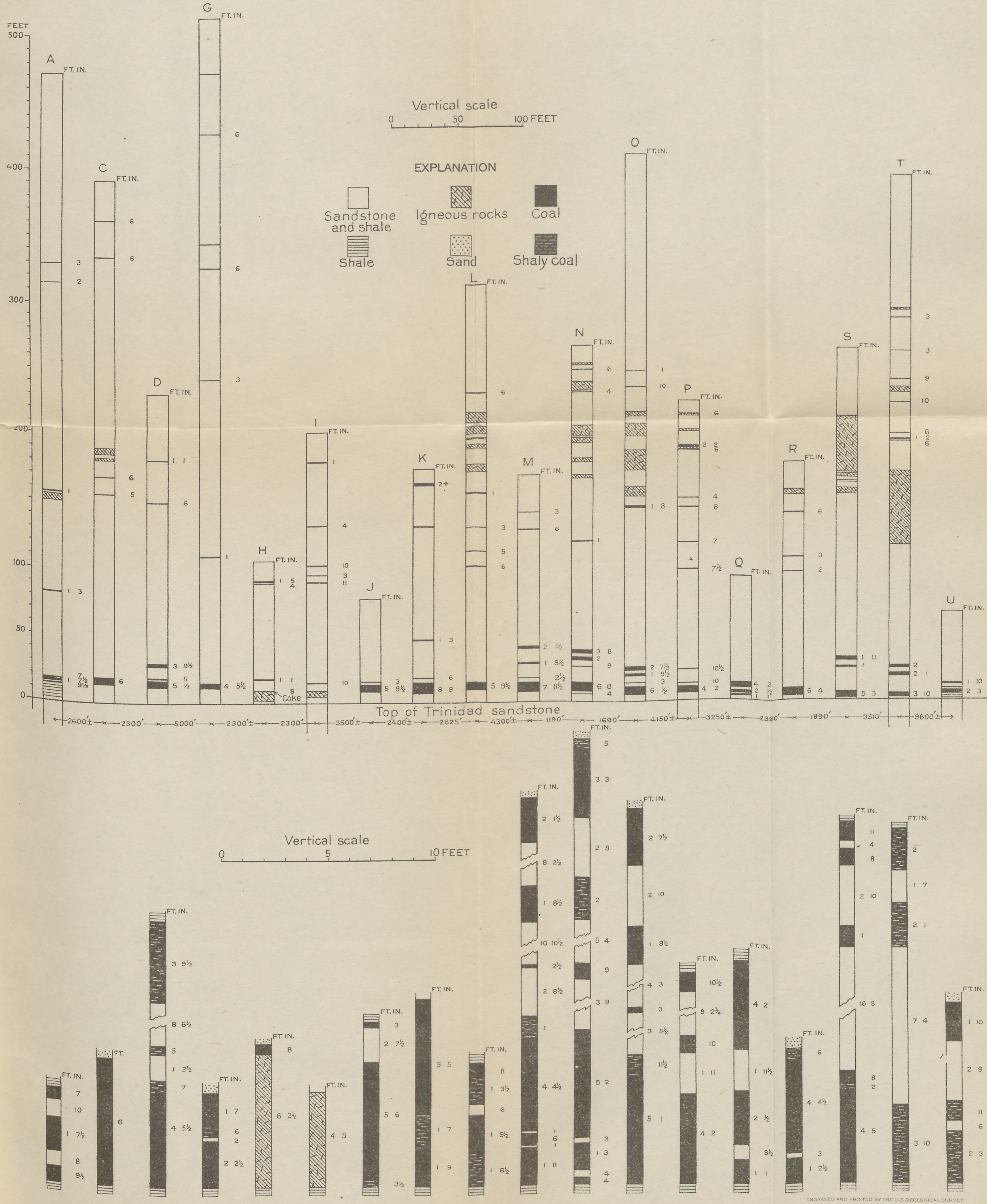
B. NEAR VIEW OF POINT OF MESA SOUTH OF GARDINER.

Shown at extreme right in *A*.



SECTIONS OF THE COAL BEDS IN THE VERMEJO FORMATION MEASURED AT THE OUTCROP AND IN MINES BETWEEN CANADIAN RIVER AND RATON, N. MEX.

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY



DIAMOND-DRILL RECORDS AND SECTIONS OF RATON COAL BED PENETRATED BY THE DRILL NEAR BLOSSBURG, N. MEX.

	Ft.	in.
Shale	36	6
Sandstone	29	3
Shale, with thin seams of coal	1	
Coal		7
Shale, with thin seams of coal		10
Coal	1	7½
Shale		8
Coal		9½
Shale and sandstone	12	4½
Sandstone	18	7
	488	4½

Another drill hole put down about 2,500 feet farther to the northeast, at locality B, revealed the presence of coal in the Raton bed that is much thicker and cleaner than the coal farther south. The rocks penetrated by the drill at locality B are as follows:

Section of rocks penetrated at locality B, north of Canadian River canyon.

[For graphic section see Pl. XII.]

	Ft.	in.
Surface material	8	
Sandstone	19	
Shale	1	11½
Coal		6
Sandstone	24	2½
Shale	2	6
Coal		6
Sandstone, shaly	23	10
Shale	5	4
Sandstone	5	2
Shale	5	7
Sandstone	9	6
Shale and sandstone	10	
Sandstone	15	11
Shale and ironstone	29	2
Sandstone, shaly	25	6
Shale	2	8
Sandstone	10	
Shale and intrusive igneous rock	13	3
Sandstone, with thin seams of coal	2	6
Shale	4	9½
Coal		6
Sandstone	12	6
Coal		5
Shale and sandstone	5	3
Sandstone	5	8
Shale	11	3
Sandstone	4	
Shale	10	8
Sandstone	13	6
Shale	4	6
Sandstone	19	7

	Ft.	in.
Shale	31	$10\frac{1}{2}$
Sandstone, with thin bands of shale	30	1
Coal	6	
Shale		5
	376	1

In a prospect opening in the gulch, at locality 193, St. John measured the section shown in Plate XI. At the fork of the canyon a little farther to the east, the writer found the relation of the coal to the neighboring rocks as represented in the section below. The sandstone above the coal, although not conglomeratic here, is probably the equivalent of the conglomerate that lies unconformably on the coal-bearing rocks on either side of this locality. The section is as follows:

Section of rocks east of locality 193, in a branch canyon north of Red River.

	Ft.	in.
Sandstone, massive, irregular bedding	20	
Shale		7
Coal	5	4
Shale	5	
Trinidad sandstone.		
	30	11

The appearance of the coal in the gulch farther to the east, at locality 194, and also farther to the south, at localities 195 to 197, inclusive, is indicated by the sections shown under these numbers in Plate XI.

On the south side of the prominent point of the mesa, at locality 198, the coal was unaffected by the igneous rock, which was intruded into the coal farther west. The sheet here is 10 feet above the coal bed. A few hundred feet farther to the northeast the following section was measured:

Section of rocks near locality 198, in north wall of Canadian River canyon.

[For graphic section see Pl. XI.]

	Ft.	in.
Shale.		
Coal		6
Shale	1	7
Sandstone	2	3
Shale		8
Coal	3	4
Shale	5	8
Coal		11
Shale	2	7
Coal, bottom not seen	3	5+
Shale	1±	
Trinidad sandstone.		
	21±	

The higher rocks are not well exposed here, but a few hundred feet to the south the uppermost coal bed of the section is exposed beneath about 11 feet of shale and this shale is in turn overlain by conglomeratic sandstone. It is therefore certain that whereas only one bed of coal occurs farther west in the Vermejo formation four occur here. Above the conglomerate the rocks are shaly for about 100 feet and contain several thin beds of coal. These rocks are known as the Sugarite zone. (See p. 144.) One bed of impure coal 2 feet 11 inches thick is about 50 feet above the conglomerate and another bed 2 feet thick is about 100 feet above it.

Northward, in the walls of the north side tributary of Canadian River canyon, east of locality 198, five prospect openings were made several years ago on one of the beds of coal, and the descriptions of them given by St. John are embodied in sections 199 to 203, inclusive, Plate XI. The coal represented by these sections may belong in the lower or in the upper bed of section 198, but certain relations observed near locality 199 indicate that it belongs to the lower one. In the east wall of the eastern fork of the canyon near this locality the following succession of beds is reported by St. John:

Section of rocks near locality 199, north of Canadian River canyon.

	Ft.	in.
Sandstone	15+	
Shale	30	
Coal and basalt	3	1
Shale	7	6
Sandstone	2	6
Shale and sandstone	46	
Coal	1	
Shale and sandstone	11	9
Coal with shale partings	7	3½
Shale	25	
Trinidad sandstone.		
	149+	

As this section was measured before the significance of the conglomeratic sandstone of this region was known, the character of the sandstone was not determined, but it is probable that the basal sandstone of the Raton formation is not conspicuously different here from other sandstones and hence is included in the 46 feet of shale and sandstone of the foregoing section. The lowest coal probably corresponds with the lowest bench of the lower bed of section 198, and the 1 foot bed with the upper bench of that bed. If this be true the higher bed of section 198 is not present at locality 199. A bed that is supposed to be the lowest was opened in several places on the outcrop east and south of the locality last mentioned and according to the measurements made by St. John has the sections shown as 199 to 203,

inclusive, on Plate XI. The coal bed here is divided by partings of shale and bone into several benches that are variable in thickness and character. The upper bed of section 198 is not mentioned in the sections made at these localities and probably does not exist there. It was not found in a well-exposed face in the canyon wall about one-fourth mile northeast of locality 203, where the following section was measured, although a thickness of 8 feet of shale above the lower bed indicates a thickening of the Vermejo formation in this direction.

Section of rocks east of locality 203, in north wall of Canadian River canyon.

[For graphic section of the lower part see Pl. II, p. 12.]

	Ft.	in.
Raton formation:		
Sandstone	30	
Shale	30	
Sandstone, cliff-making	20	
Shale with thin beds of sandstone	50	
Sandstone, cliff-making	30	
Shale, not continuously exposed	50	
Sandstone, cliff-making	30	
Igneous rock	3	
Shale	35	
Shale, black, carbonaceous, with thin beds of coal	3	
Shale with thin beds of sandstone	80	
Sandstone	10	
Unconformity.		
Vermejo formation:		
Shale	8	
Coal	3	6
Shale	2	
Coal	1	
Shale	2	
Coal		6
Shale	3	
Trinidad sandstone, rusty layer at top	100±	
Pierre shale.		
	491±	

At locality 204, in the Raton quadrangle, St. John measured the section given in Plate XI. The lower bed of coal, which at the localities just described showed a tendency to break up and merge laterally into shale, is here represented by only thin seams of coal. The upper bed of coal is present at this locality but is not thick enough to be of much value. A section was measured near this locality for the purpose of showing the relation of the coal beds to rocks above and below them. The lower coal bed was not found where the section was measured, and a sill of igneous rock intruded above the upper bed has obscured the relations to some extent. The section is given as 204 on Plate XI.

At locality 205 four thin beds of coal are reported, none of which is thick enough to be of much value. Their relation to the coal beds

of neighboring sections is shown on Plate XI. Farther southeast, near locality 206, St. John measured another section given under this number on the same plate. The exact locality is not indicated on St. John's map, but it can not be far from the point indicated on the map as locality 207. Farther east, where the outcrop of the coal bed turns north, the section shown as 207 on Plate II was measured to show the stratigraphic relations of the coal beds to the rocks above and below them. The general relations of the several formations described in this bulletin are plainly exhibited in this part of the field. The Pierre shale (see Pl. X, *A*) crops out in the lower part of the steep slope, and the Trinidad sandstone appears as a conspicuous white band in the side of the mesa. Above this sandstone lie the coal-bearing Vermejo and Raton formations. The first three of these formations are shown in greater detail in Plate X, *B* (p. 78). (See also Pl. XVII, *A*, p. 152.)

The higher coal beds of the section are described on page 154 under the heading "Sugarite coal."

The coal beds of the Vermejo formation occur in the isolated area of coal-bearing rocks on the point of the mesa farther east, but no observations were made on them.

At locality 208 the section shown in Plate XI was measured. Near this locality St. John reports the two beds of coal as shown in section near 208a and near 208b, Plate II. The writer confirmed his observations. One-fourth of a mile farther to the north, however, the upper bed was not found, but on the point of the mesa north of this locality both beds were found, as shown in the following section.

Section of rocks north of locality 208, on the slope south of Gardiner.

	Ft.	in.
Sandstone	20	
Coal	1	
Shale	10	
Coal	3	6
Shale and sandstone	50	
Igneous rock intruded into sandstone and shale	20	
Coal	3	10
Shale		10
Coal		4
Shale	20	
Coal	1	
Shale	2	6
Coal	2	1
Shale		3
Coal	1	
Shale, carbonaceous	20	
Trinidad sandstone.		
	156	4

The pebbles in the conglomeratic sandstone, which lies above the Raton coal, are not numerous and might easily escape the notice of one who was not looking especially for them. However, the writer found in it several quartz and chert pebbles having a maximum diameter of half an inch. Farther north, in Gardiner Canyon, the conglomeratic sandstone was traced along the outcrop and found in several places to rest with irregular base on the Vermejo beds. The two coal beds of the section at locality 208 seem to be persistent to the northwest, and according to St. John they occur at locality 209. (See Pl. XI.)

In the north wall of the gulch in which the last locality described is situated St. John measured the following section, which shows the occurrence not only of the two beds of coal in the Vermejo formation but also the higher coal that is described on page 152 as the Sugarite coal.

Section near locality 209, south of Gardiner.

	Ft.	in.
Sandstone	17+	
Coal		8
Shale	8	
Coal	3	
Shale	3	6
Sandstone	2	
Shale	4	
Sandstone (probably the conglomeratic sandstone at the base of the Raton formation)	16	
Coal	2	2
Shale	12	6
Coal	1	
Shale	2	2
Coal	3	
Shale	11	
Trinidad sandstone.		
	86+	

In the south wall of Gardiner Canyon the two main beds of coal in the Vermejo formation are persistent, and both were found at locality 210. (See Pl. XI.) Farther west the lower coal thickens and has been measured at localities 211 to 214, inclusive (Pl. XI). These old prospect openings, long since destroyed, were probably on the lower bed, but this is not certain. Near the mouth of the abandoned mine south of locality 214 the writer measured the following section:

Section of rocks near mouth of old Gardiner mine, in south wall of Gardiner Canyon.

[For graphic section see 214a, Pl. II, p. 12.]

	Feet.
Sandstone, conglomeratic.	
Sandstone, not well exposed	14
Coal	6±
Shale	8
Coal	6
Shale	7+
Trinidad sandstone.	
	41±

The higher bed was not well exposed, and no exact measurement was obtained. The coal at the mouth of the mine farther south, presumably the lower bed, is reported by St. John to be 7 feet thick and the bed increases in thickness somewhat toward the west and north. In the south fork of Gardiner Canyon, at locality 215, it has a thin layer of bone near the top which toward the west seems to develop into a shale that at locality 216 is 1 foot thick. Also, at this locality the main coal is separated into two benches by one-half inch of bone, which seems to thicken toward the east and to represent the 1 foot of shale in section 217.

Near one of the openings of the abandoned mine St. John reports the following section, which can not now be definitely located but which is given here for the purpose of showing the relation of the coal beds to the rocks above and below it.

Section of rocks near locality 217, in Gardiner Canyon.

	Ft.	in.
Sandstone	15±	
Shale	2	
Coal		6
Shale	5	
Coal	2	6
Shale	6	6
Sandstone	5±	
Shale	10±	
Coal	8	3
Shale	27	
Trinidad sandstone.		
	81±	

East of this point a shale parting develops in the lower coal and thickens to the east and north. The bench below this parting becomes thinner to the north and east. (See Pl. XI.) This shale is only 1 foot thick at locality 217, but at the mouth of the old mine, at locality 218, it practically replaces the lower bench of coal, whereas the bench above it maintains a good thickness. The details of the bed still farther to the east are shown in sections 219 to 221, inclusive, Plate XI. The relations of the coal beds to rocks above and below them are shown in Plate II (p. 12.) Section 218a was measured in

the canyon wall a few hundred feet east of the old mine opening, and only the upper coal bed was found. Section 219a was measured a little west of locality 219, and section 221 was measured at the spur north of Gardiner marked by this number on the map (Pl. I).

Farther north, at locality 222, the upper bench thickens, but the lower bench is not known to occur here. However, it is reported from locality 223 in the gulch farther north, where both benches were found.

In the west wall of Dillon Canyon, west of Blossburg and probably near locality 223, although it can not now be definitely located, St. John measured the following section, which shows that both the benches or beds of coal occur here:

Section of rocks near locality 223, west of Blossburg.

	Ft.	in.
Sandstone	11	
Not exposed	9	
Sandstone (probably the conglomeratic sandstone of this region)	7	
Shale, with seams of coal	5	
Coal	7	10
Shale	13	8
Coal	1	10
Shale	3	
Trinidad sandstone.		
	58	4

Farther to the northwest, in the south wall of Seeley Canyon just east of the old mine opening, at locality 224, the upper coal has the appearance indicated by the section shown in Plate XI. Either the lower coal has thinned out south of locality 224 or has thickened to become the main bed, whereas the upper one has disappeared. It is impossible without more detailed information than is now available, and probably without careful observations in the mine entries that are now inaccessible, to determine the exact relations of the several benches and beds of coal of this region to each other and to the associated rocks.

A section was examined in the north wall of Seeley Canyon for the purpose of ascertaining the stratigraphic relations of the several beds. This section was measured before the coal-bearing rocks were subdivided into formations; hence the line of separation between the Vermejo and Raton formations can not be definitely drawn; but the 6-foot sandstone over the Raton coal probably marks the base of the Raton formation. This section is as follows:

Section of rocks near locality 225, in the north wall of Seeley Canyon.

	Feet.
Sandstone and sandy shale	40
Shale, carbonaceous, with 6 inches or more of coal	2
Shale	10
Sandstone, massive, cliff-making	70
Shale	20
Sandstone, cliff-making	40
Sandstone, in thin beds, with shale partings	45
Sandstone	20
Igneous rock (andesite)	6
Covered	95
Sandstone	15
Shale, not well exposed	55
Coal, impure (Sugarite bed ?)	3
Shale, with thin beds of sandstone	40
Igneous rock	2
Shale and sandstone, alternating beds	30
Sandstone	6
Coal, Raton bed	6
Shale	(?)
Trinidad sandstone.	
	505

The character of the coal bed between Seeley and Dutchman canyons is best indicated by the sections from the mine workings, and its description is given in that of the Blossburg mine. A section measured in the south wall of Dutchman Canyon, at locality 225, is shown in Plate XI. In the north wall of this canyon at locality 226, near the mouth of the Dutchman mine, the following section showing the relation of the coal bed to neighboring rocks was observed:

Section of rocks at locality 226.

	Ft.	in.
Sandstone, conglomeratic	10+	
Sandstone, micaceous, friable	4	
Shale	16	
Coal	4	8
Shale	10	
Trinidad sandstone.		
	44+	8

The sandstone at the top of this section is the base of the Raton formation and is variable in thickness and character in this region. In one place, near locality 226, where it is perfectly exposed, it ranges in thickness from 2 to 20 feet in a horizontal distance of 100 feet.

A little farther to the east the writer measured the section shown as 226a in Plate II (p. 12), and at the point still farther east, at locality 227, the following section is exposed:

Section of rocks at locality 227, at junction of Dillon and Dutchman canyons.

	Ft.	in.
Sandstone	10±	
Shale	12	
Sandstone	1	
Shale	7	4
Coal		4
Shale	1	4
Coal	5	1½
Shale	6	6
Trinidad sandstone.		
	43±	

The details of the main bench of coal are shown in section 227 in Plate XI. The relations of the coal bed to the rocks above and below it are shown in the section given below.

Section of rocks near locality 227, near the junction of Dillon and Wheatcroft canyons.

	Ft.	in.
Sandstone, slightly conglomeratic	14±	
Shale	21	6
Coal		6
Shale	3	
Coal	4	6
Shale	8	
Trinidad sandstone.		
	51±	

From this section it appears that the shale above the main bench of coal thickens toward the north, and at the mouth of an old mine, locality 229, it is 2 feet 9 inches thick. The bed at this locality, including this shale, is reported to be 8 feet 1 inch thick. This old mine was reopened in 1918 under the name Swastika mine.

In the bottom of the first gulch, locally known as Wheatcroft Canyon, north of Dutchman Canyon, this coal bed is 4 feet 5 inches thick and has a little less thickness farther north, at locality 228.

The conglomeratic sandstone, which is the base of the Raton formation, is persistent in the vicinity of Blossburg, forming in many places a well-defined cliff. The rocks between this sandstone and the Trinidad sandstone are all that here represent the Vermejo formation.

The next exposure of the coal north of the Swastika mine is at the point where the coal bed crosses Dillon Creek. Two prominent beds of coal are here separated by partings of shale, which may represent the shale just described as occurring near the top of the coal bed farther south. Possibly also a certain bony or shaly layer, in

the coal bed of the old Blossburg mine to the south and in the Dutchman mine to the southwest, corresponds to this shale. In the bed of Dillon Creek, at locality 230, two beds of coal were opened several years ago in what is known as mine No. 1 of the Raton Coal & Coke Co., but the old entry was inaccessible at the time of the writer's investigation. However, near the mouth of the old opening the rocks are well exposed and the following section of them was measured:

Section of rocks exposed where the outcrop of the Raton coal bed crosses Dillon Creek.

[See section 230, Pl. XI, p. 78.]

	Ft.	in.
Sandstone	6	
Shale	3	6
Sandstone	1	
Shale	4	
Sandstone	4	
Shale	1	3
Coal	4	
Shale		4
Coal	1	
Shale		10
Coal	4	
Shale	6±	
	35	11±

The same beds were opened in a mine entry that was run in on them in the opposite wall of the canyon at locality 231, where essentially the same conditions as those just described were found, except that the two benches of coal are here separated by 2 feet 9 inches of shale. The coal bed aggregated a thickness of 8 feet 1 inch at this place.

Another old opening, known as mine No. 2 of the Raton Coal & Coke Co., which was operated several years ago, opens in the gulch at locality 232. Such records as have been preserved indicate that the coal in this mine ranged from 4 feet to 4 feet 8 inches in thickness, the upper half of which was somewhat bony. Comparison of the sections in this mine with those in mine No. 1 indicate that this coal is probably the lower bench of the bed and that this bench thins and the coal becomes impure toward the northeast. For about a mile south of the last-mentioned locality the rocks at the horizon of the Raton coal in the east wall of Dillon Canyon are not well exposed, but a few good measurements of the bed were obtained in old prospect openings. At locality 233, about one-fourth of a mile south of mine No. 2, a section given under No. 233 in Plate XI was measured. Opposite the mouth of Dutchman Canyon, at localities 234 and 235, the same bed has the appearance shown in the sections bearing the same numbers on this plate.

In the point between Dillon and Coxe canyons, at locality 236, only the main bench of the coal bed, 3 feet 6 inches thick, was found, and the same bench in Coxe Canyon, locality 237, is 4 feet 9 inches thick. This coal bed here occurs 15 feet above the top of the Trinidad sandstone. A little farther south it is 5 feet 6 inches thick at locality 238, where a section of rocks from the Trinidad sandstone to the top of the mesa was measured. This section indicates that the coal bed described from the last several localities is the third bed above the base of the Vermejo formation. The section is as follows:

Section of rocks measured near locality 239, in east wall of Coxe Canyon.

[For graphic section in part see Pl. II, p. 12.]

	Ft.	in.
Raton formation:		
Sandstone, cliff-making	20	
Covered	20	
Shale, carbonaceous, with thin beds of coal	5±	
Shale	15	
Coal	1	
Shale	15	
Coal with partings of shale, Sugarite bed	2	6
Shale, sandy	10	
Coal		6
Shale, not well exposed	65	
Sandstone, locally conglomeratic	10	
Unconformity.		
Vermejo formation:		
Shale	8	
Coal	5	6
Shale	8	
Coal	2	
Shale	16	
Sandstone	1	
Coal		11
Trinidad sandstone:		
Sandstone, white, massive	40	
Shale, carbonaceous, with thin beds of coal	10	
Sandstone, white, massive	50±	
	305±	

The main coal bed has been opened in the new Gardiner mine, which lies immediately south of this locality. At the northernmost opening (locality 239) the coal is 7 feet thick and is 6 feet thick in the next opening to the south at locality 240. At the main opening of the mine (locality 241) the bed has the section shown in Plate XI. The lowest or 11-inch bed of the section measured in the east wall of Coxe Canyon (near locality 239) was not found here but may have been overlooked because of poor exposures. Its presence farther south and east indicates that it is probably present beneath

the mine workings. It was found in the gulch at locality 242, where a section was measured as follows:

Section of rocks at locality 242, in gulch south of Gardiner mine.

	Ft.	in.
Sandstone.		
Covered	8	
Coal	5	6
Shale	8	
Coal	2	
Shale	16	
Sandstone	1	
Coal		11
Trinidad sandstone.		
	41	5

The beds near the mouth of the Gardiner mine are badly broken by small faults. A large number of slips having displacements of a few inches to a foot or more were observed, and similar features have been noted also in the mine workings. About three-fourths of a mile farther south, at locality 243, the coal-bearing rocks are well exposed and a section of them was examined and measured. This section is shown in Plate II (p. 12), where the stratigraphic relations of the beds are illustrated, and also in Plate XI, where the details of the coal beds are shown.

The coal beds are persistent in this region and seem to be fairly uniform in thickness and character. All four of them were found in the canyon east of the new Gardiner mine. Sections of the coal beds at localities 244 to 247, inclusive, at these localities are shown in Plate XI.

In the next canyon to the east, at locality 248, three beds of coal were found in the Vermejo formation, but the intervals between them were not determined because of poor exposures. The lowest coal is 1 foot 11 inches thick and has sandstone below and shale above it. The middle one is 3 feet 7 inches thick and has shale above and below it, and the highest is 3 feet 6 inches thick. The relations of these beds to those at neighboring localities are shown graphically in Plate XI. In the east wall of the canyon, at locality 249, the rocks from the Trinidad sandstone to the top of the mesa were examined in detail, and the results are shown in Plate II. The details of the coal beds and their relation to those of near-by localities are shown in section 249. The highest bed of coal described from localities farther west was not found at this locality, nor was it found in any of the sections examined farther to the east and north. Also, the lowest coal bed thins toward the east and finally disappears. It is only 3 to 5 inches thick in the point of the mesa north of the cemetery. In the south slope of this point, near locality 250, a

section of the rocks from the Trinidad sandstone to the top of the mesa was examined in detail as follows:

Section of rocks at locality 250, in point of mesa north of cemetery near Raton.

[For graphic section see Pl. II, p. 12.]

	Ft.	in.
Sandstone and shale	27	
Coal, not well exposed	(?)	
Shale	15	
Sandstone	12	
Shale	26	
Coal, shaly		4+
Shale	18	
Sandstone	10	
Shale, sandy	8	
Shale	3	
Coal	4	7+
Shale	9	
Coal	3	8
Shale		6
Sandstone	4	6
Shale		4
Coal		5
Shale	2	4
Trinidad sandstone.		
	148+	

Two mine entries were driven in on the higher bed of coal near this locality several years ago, but the openings were inaccessible at the time of the writer's investigation. Both the lower and upper coal beds appear to be somewhat shaly, but no satisfactory details of the beds were obtained.

A little farther to the north, near a 3-foot dike that cuts through this point of the mesa, the lowest bed is represented by a few inches of bony coal. The middle bed contains 3 feet 7 inches of coal with shale above and below it, but the coal is bony. The highest coal, 3 feet above this middle bed, is 4 feet 1 inch thick and has shale above and below it. A few hundred feet farther north, in the west wall of the embayment west of the town of Raton, a section was examined in detail at locality 251. The stratigraphic relations here are illustrated in Plate II (p. 12), and the relations of the coal beds to those of other localities are shown in Plate XI. The two main coal beds are exposed in several places in this embayment, and a number of prospects have been opened on them, but these were not accessible at the time of the writer's investigation.

In the north wall of this embayment, near an old abandoned mine, at locality 252, a section of the coal bed was measured. (See Pl. II.) The rocks above the horizon of the main coal beds are not well exposed here, but this part of the section has been plotted for the purpose of

showing the position of a higher bed of coal, which is described on page 152 as the Sugarite coal bed.

The coal beds of the Vermejo formation are well exposed in rock cuts on the Scenic Highway west of Goat Hill, at locality 253, where the section given in Plate XI was measured. At this locality the upper surface of the higher bed shows erosion, and a fresh cut revealed a thickness of 4 feet 6 inches of coal. In a distance of 10 feet, however, the coal is reduced to a thickness of 3 feet. The basal sandstone of the Raton formation lies on this eroded surface of the coal. These coal beds outcrop in Goat Hill, but the coal of this isolated area probably has little commercial value. The beds were examined at several localities farther north, and the sections exposed at localities 254 to 259 are shown in Plate XI.

Where the outcrop of the coal bed crosses Railroad Canyon, locality 260, north of Raton, only one bed of coal was found. This bed has the section shown in Plate XI. It is probably the higher bed of the sections west of Railroad Canyon.

On the east side of the gulch, at locality 261, this coal is 4 feet 7 inches thick and has shale above and below it. The lower coal bed was not found here, but it may have been obscured, for it occurs at the stone quarry east of Railroad Canyon (locality 262) about one-fourth of a mile farther south. Here it is 2 feet 3 inches thick and has shale above and below it. The upper bed at this locality is 4 feet 2 inches thick and lies between shale beds. In the reentrant angle farther east, at locality 263, the lower bed was not found, but the upper one is well exposed and contains 4 feet 4 inches of coal. Its relations to other rocks are indicated in Plate II.

Still farther east, near the mouth of an old mine entry, at locality 264, the coal is 3 feet 9 inches thick at the outcrop of the bed and underlain and overlain by shale, but its thickness in the old mine is reported as averaging about 4 feet 6 inches. This bed, which is the upper bed of the section previously described, lies 15 feet above the base of the coal-bearing rocks. The lower bed was not found here but is probably represented by thin seams of coal that occur in the shale below the main coal.

The abandoned mine at this locality is known as the old Smith mine No. 2. It supplied coal for domestic fuel in Raton for about eleven years. It was opened by Henry Smith and operated first by him but later by Albert G. Shaw, A. L. Hobbs, and finally by A. Hallas. Before it was finally abandoned the main entry had been driven in on the bed about 2,000 feet.

East of this mine the relations of the beds are somewhat obscure. The main coal bed extends for some distance to the east but soon disappears. The sandstone at the base of the Raton formation is not prominent in this vicinity, but the relations previously described war-

rant the supposition that its disappearance is due to removal by erosion. The bed was not found at locality 265, but thin coals that were observed at the horizon of the lower bed are shown in Plate II and also in sections 266 and 267. Still farther east the Raton coal bed and the Vermejo formation thins out and the conglomeratic sandstone at the base of the Raton formation rests on the Trinidad sandstone. For this reason it seems probable that the main coal bed was eroded prior to the deposition of the conglomerate rather than that the coal thins out because of nondeposition.

MINES.

GENERAL FEATURES.

Several mines have been opened west of Dillon Canyon. The principal ones, all of which had been abandoned before the writer's investigation, are as follows: In Gardiner Canyon a mine now generally known as the old Gardiner mine, but formerly called Blossburg No. 4, extended from a point about 1,000 feet north of the outcrop in Canadian River Canyon northward to Seeley Canyon. A mine between Seeley and Dutchman canyons is known as the old Dutchman mine and one north of the Dutchman Canyon is known as the new Dutchman mine. The Blossburg mine No. 4 was opened about 1882 and was operated by the Atchison, Topeka & Santa Fe Railway Co. until 1896, after which it was operated by the Raton Coal & Coke Co. until 1898, when it was finally abandoned, and all details that are now available concerning it are those recorded on mine maps and charts, only a few of which have been preserved. A report made to the coal company by the late Orestes St. John describes the coal as follows:

> Generally the deposit is remarkably free from shale streaks, and the slaty matter, except in the thinner portions of the bed, where it may be more or less disseminated, is usually concentrated in bone bands either in the top or in the bottom of the bed. The coal is everywhere based upon shale with either shale or sandstone roof; in the former instance when beyond the slacking influence of exposure to excess of moisture along the water line outcrop in the superficial drainage depressions, the shale constitutes a reasonably firm top and where the sandstone comes down upon coal no better roof for economic mining could be desired.

SECTIONS OF COAL BED IN MINES AND DRILL RECORDS IN BLOSSBURG DISTRICT.

A few of the sections of the coal bed measured in the mine entries now abandoned have been included in this report. They have been selected from among a considerable number of similar sections which have been preserved in the records of the old mines. They probably represent correctly the character of the coal bed and such variations as occur within the developed parts, but in considering these sections the reader should remember that only those portions of a coal bed are removed that contain coal thick enough and clean enough

for profitable mining. A bench of coal either below or above the main bed may be represented in some of the measured sections and not in others. The details of the coal bed are shown graphically in Plate XI. A number of drill holes were put down in advance of the mine workings to test the character of the bed. Records of these drill holes are included in the description of the mines, although they are referred to in other parts of the paper. They are shown graphically in Plate XII.

The workings of the old Gardiner mine were driven southward to a point about 1,000 feet from locality 201, on the outcrop of the coal bed in a north-side tributary of Canadian River canyon, where, as previously described, a thick bed of coal was opened at the outcrop. The coal bed was only 3 feet 10½ inches thick at the southwestern extremity of the mine, near locality B, where it was penetrated by the drill, and is shaly farther west at locality A. (See Pl. XII, p. 78. Localities are indicated on the map, Pl. I.) Only one bed of coal was found in the Vermejo formation in these drill holes instead of the two that occur farther to the east and north. The coal at localities A and B is rather thin and shaly, but the bed increases in thickness toward the north and east to a maximum of more than 8 feet. The average for the entire mine is reported to be 6 feet.

In the drill hole put down in Gardiner Canyon at locality C, 2,500 feet northwest of locality A, only one bed of coal 6 feet thick was found, but 2,300 feet farther east two beds were penetrated by the drill at locality D. The details of these beds are presented in section D in Plate XII. The presence of two thick beds of coal at this point and also in Gardiner Canyon farther east, and the presence of only one to the west and south, suggests that here, as elsewhere in the Raton field, an unconformity occurs, possibly at the base of the 26-foot sandstone of the following record, and that the upper bed of coal was eroded in some places prior to the deposition of this sandstone. The drill record is as follows:

Section of rocks at locality D, west of Gardiner.

[Adapted from a drill record. For graphic section see Pl. XII.]

	Ft.	in.
Surface material	7	
Shale	2	
Sandstone	38	1
Shale		6
Coal	1	1
Shale	6	
Sandstone, shaly	7	11
Shale, with thin seam of coal	9	7
Sandstone	8	7½
Coal		6
Shale, sandy	14	4

	Ft.	in.
Sandstone	24	10
Shale	22	6¼
Sandstone	13	1½
Shale	8	10
Sandstone, shaly	26	8
Shale	5	5½
Coal, shaly	3	9½
Shale	8	6½
Coal, shaly		5
Shale	1	2½
Coal, shaly		7
Coal	4	5½
Shale		10½
	216	11½

Still farther north, where the main or lower coal bed was penetrated by the drill at locality E, the coal is only 4 feet 1 inch thick, and it is still thinner in the western part of the old Gardiner mine, where a thickness of 3 feet of coal is reported at locality 268. However, it thickens again toward the northeast and is 5 feet 5 inches thick at locality 269.

The coal bed was opened in the north fork of Gardiner Canyon, but the coal was very bony. Its character is best indicated by sections 270 to 272 in Plate XI. At locality 273 the coal is only 4 feet 3 inches thick but is of much better quality than it is farther east. Apparently this thickness is maintained for a considerable distance to the west, although the coal is bony, as shown by the drill section at locality G in Plate XII. The full record of the drill prospect indicates that only one bed of coal occurs here in the Vermejo formation and that no coal of economic value occurs above it. The record is as follows:

Section of rocks at locality G, west of Gardiner.

[Adapted from a drill record. For graphic section see Pl. XII.]

	Ft.	in.
Surface material	28	
Shale	5	
Sandstone	4	
Shale, with thin seams of coal	7	10
Shale	7	½
Sandstone	30	9½
Shale	3	
Coal, shaly		6
Shale and sandstone	29	2
Sandstone	50	2
Shale, with 6-inch coal in middle	6	
Sandstone	11	
Shale	4	
Coal, shaly		6
Sandstone	27	

	Ft.	in.
Shale	5	6
Sandstone	13	6
Shale	4	
Sandstone	24	
Shale	8	5
Coal		3
Sandstone	7	10
Shale, sandy	7	6
Sandstone	5	
Shale and intrusive igneous rock	2	5
Sandstone	17	7
Shale	6	6
Sandstone	10	
Shale	3	
Sandstone	8	
Shale	4	
Sandstone	9	6
Shale	12	
Sandstone	25	6
Shale, with thin seam of coal at base	2	
Sandstone	8	10
Shale		6
Coal	1	
Shale	6	8
Sandstone	7	8
Shale	8	8
Sandstone	16	2
Shale	5	2
Sandstone	15	10
Shale	3	
Sandstone	11	8
Shale, sandy	5	10½
Sandstone	6	
Shale	6	½
Sandstone	1	7½
Coal	1	7
Coal, shaly		6
Shale		2
Coal	2	2½
Shale		4
	500	2

North of locality 273, about 1,500 feet south of the outcrop of the coal in Seeley Canyon, a dike 50 to 75 feet thick was penetrated by the main entry of the Blossburg mine. It is nearly vertical and trends a little north of west. It was encountered again in the mine about 1,000 feet east of the main entry but has not been found at the surface. Igneous rock was encountered also in the cross entries to the west, so that development work west of the main entry between locality 273 and Seeley Canyon to the north was stopped. These igneous intrusions seem to extend for a considerable distance to the

west and north, at least as far as locality I. In a drill hole put down in the south fork of Seeley Canyon at locality H, about 2,000 feet west of the mouth of the old mine, a sheet of igneous rock was found under a thin bed of coked coal. The drill here penetrated a higher coal bed, which, although only 1 foot 1 inch thick, probably represents the upper bed described from several localities in this district but which is not present in others. The rocks penetrated by the drill in this locality are as follows:

Section of rocks at locality H, west of Gardiner.

[Adapted from a drill record. For graphic section see Pl. XII.]

	Ft.	in.
Surface material	14	
Sandstone		7
Coal	1	5
Shale	1	
Coal		4
Sandstone and shale	68	3
Coal, shaly	1	1
Shale	1	7½
Sandstone	8	1
Coal, coked		8
Igneous intrusive rock	6	2½
Shale, baked		11
	104	2

At locality 274 the coal is 5 feet thick and a considerable area of good coal was found between this locality and the outcrop to the east. North of Seeley Canyon the coal is destroyed in several places by intrusions of igneous rock, and mining operations were stopped because of them at the western extremity of the old Dutchman mine. That these intrusions probably extend at least 2,000 feet west of the workings of the old mine is indicated by the absence of the Raton coal and the presence in its place of igneous rock at locality I in the north fork of Seeley Canyon, where the drill penetrated the following rocks:

Section of rocks at locality I, west of Gardiner.

[Adapted from a drill record. For graphic section, see Pl. XII.]

	Ft.	in.
Surface material	12	
Sandstone and shale	9	
Coal	1	
Sandstone and shale	46	5
Coal		4
Sandstone and shale	30	3
Coal		10
Sandstone and shale	5	6
Coal		3

	Ft.	in.
Sandstone and shale	4	11
Coal		11
Sandstone and shale	74	
Coal		10
Sandstone and shale	5	4
Igneous rock	4	5
Sandstone and shale	24	11
	220	11

Orestes St. John, the geologist of the mining company, states that the coal bed in the main workings between Gardiner and Seeley canyons ranges from 3 feet 11 inches to 8 feet, with an average of 6 feet. In the mine north of Seeley Canyon, known as the old Dutchman mine, the coal bed seems to have been relatively regular in thickness and character. In the southern part of the mine there was a bony parting which, however, disappeared farther north. Sections 275 to 277 in Plate XI represent the coal bed in this mine. In the new Dutchman mine, north of Dutchman Canyon, the coal is relatively uniform in thickness, although a persistent bony layer occurs near the top of the bed.

The conditions of the coal bed in this vicinity are favorable for profitable mining, and considerable prospecting was done with the drill to the west and north. In addition to showing the thickness and character of the Raton coal bed, the records of these drill holes are useful in working out several features of the geology of the region, and they are therefore given in full here.

About 500 feet west of the western opening of the new Dutchman mine a drill hole was put down in Dutchman Canyon at locality J on the map (Pl. XII), with the results given below:

Section of rocks at locality J, west of Gardiner.

[Adapted from a drill record. For graphic section see Pl. XII, p. 78.]

	Ft.	in.
Surface material	24	
Sandstone and shale	37	9
Coal		3
Sandstone	1	8
Shale		11½
Coal, shaly		10
Coal		11
Coal, with thin seams of shale	1	6
Coal	2	3½
Coal, shaly		3½
Shale	1	10
	72	3½

The main bed of coal thickens toward the west and is reported to be 5 feet thick in the mine at locality 278, 6 feet 11 inches thick with

a 5-inch parting at locality 279, and 7 feet 10 inches thick at locality 280. Near locality 280 a drill hole was put down at locality K and later a shaft was sunk in practically the same place. The following rocks were penetrated:

Section of rocks at locality K, west of Gardiner.

[Adapted from a drill record. For graphic section see Pl. XII, p. 78.]

	Ft.	in.
Surface material	10	
Coal	2+	
Sandstone and shale	29	
Intrusive igneous rock		10
Sandstone and shale	82	11
Coal	1	3
Sandstone	17	4
Shale	9	11
Coal		6
Shale	3	3
Coal	5	5
Coal, shaly	1	7
Coal	1	9
Shale	1	8
Sandstone		3
	167	8

The main coal bed near the bottom of the foregoing section is the one developed in the mine to the north and the 6-inch bed above it probably is the attenuated edge of the upper bed described farther to the southeast.

Another drill hole was put down about 2,825 feet farther up the south fork of Dutchman Canyon at locality L. Coal presumably of the Raton bed was penetrated, but this bed is thinner than the main coal farther east, and the 6-inch bed at locality K seems to have disappeared. The rocks penetrated by the drill at locality L are as follows:

Section of rocks at locality L, west of Gardiner.

[Adapted from a drill record. For graphic section see Pl. XII, p. 78.]

	Ft.	in.
Surface material	14	
Sandstone and shale	67	
Coal		6
Sandstone and shale	14	
Igneous intrusive rock	7	6
Shale	3	
Igneous intrusive rock	6	
Sandstone and shale	3	
Igneous intrusive rock	1	
Shale	4	
Igneous intrusive rock	2	6
Sandstone and shale	12	
Igneous intrusive rock	6	6

	Ft.	in.
Sandstone and shale	14	6
Coal	1	
Sandstone and shale	25	3
Coal		3
Sandstone and shale	17	
Coal		5
Sandstone and shale	11	7
Coal		6
Sandstone and shale	61	6
Sandstone, massive	16	6
Shale	7	3½
Coal		8
Coal, shaly above	1	3½
Shale		6
Coal	1	9½
Coal, shaly		3
Coal with streaks of shale	1	3½
Shale	2	2
	304	9

In the north branch of Dutchman Canyon, about 1,500 feet upstream from the fork of the creek, at locality M, the drill showed the succession of rocks given below. The main entry of the mine was later driven near this drill prospect, and the coal shown at the base of the section was mined out. The record is as follows:

Section of rocks at locality M, west of Gardiner.

[Adapted from a drill record. For graphic section see Pl. XII, p. 78.]

	Ft.	in.
Surface material	8	6
Sandstone and shale	21	6
Coal		3
Sandstone and shale	11	9
Coal		6
Sandstone and shale	86	8
Coal	2	1½
Sandstone and shale	8	2½
Coal, shaly	1	8½
Shale	2	8½
Sandstone	1	6
Shale	6	8
Coal		2½
Shale	2	8½
Coal, shaly	1	
Coal	4	4½
Shale		1
Coal		6
Shale		1
Coal	1	11
Shale	1	9½
	164	9

A little farther northwest, at localities 281 and 282, the coal has the character shown in Pl. XI, (p. 78).

A drill hole at locality N, up the canyon about 1,190 feet from locality M, shows the presence of a thick bed at the horizon of the main coal and also coal beds at higher horizons which seem to correspond to the thin coals found above the main bed in several other places in this region. The drill record is as follows:

Section of rocks at locality N, west of Gardiner.

[Adapted from a drill record. For graphic section see Pl. XII, p. 78.]

	Ft.	in.
Surface material	4	
Shale	9	6
Igneous intrusive	1	10
Sandstone	3	
Coal		6
Shale	8	10
Igneous intrusive	6	9
Coal		4
Sandsone and shale	26	2
Igneous intrusive	13	2
Sandstone	12	10
Igneous intrusive	3	2
Sandstone and shale	6	11
Igneous intrusive	2	5
Sandstone and shale	45	9
Coal, shaly	1	
Sandstone and shale	86	1
Coal, shaly		5
Coal	3	3
Shale	2	9
Coal, shaly	2	
Shale	5	4
Coal		9
Shale		7
Sandstone	1	6
Shale	1	8
Coal	5	2
Shale		3
Coal, shaly	1	3
Shale		4
Coal		4
Shale	2	1½
Sandstone	1	10½
	261	10

Still farther up the canyon, about 1,690 feet above locality N, the last drill hole of this series was put down, at locality O. A good body of coal was found in the main bed, and above it lay the thin beds previously described as occurring above it in several prospects of this region. Above the highest coal of the lower group of beds

lies a thick sandstone that may represent the base of the Raton formation. Unfortunately nothing in these drill records indicates definitely where the drills passed from the Raton to the Vermejo formation. However, at the surface exposures, where the structural relations can be determined, some of the higher coal beds in the Vermejo formations have been removed by erosion before the overlying Raton formation was laid down and the lowest bed of the Raton formation consists of massive sandstone. The following rocks were penetrated by the drill at this locality:

Section of rocks at locality O', west of Gardiner.

[Adapted from a drill record. For graphic section see Pl. XII.]

	Ft.	in.
Surface material	5	9
Sandstone	25	3
Shale		9
Sandstone	10	3
Shale	5	2
Sandstone	13	10
Shale, with a thin seam of coal	5	
Sandstone	7	6
Shale	4	
Sandstone	9	
Shale	2	3
Sandstone	13	
Shale	4	7
Sandstone	20	5
Shale	2	9
Sandstone	32	3
Shale	11	4
Coal		10
Shale		11
Sandstone	5	3
Igneous intrusive rock		4
Shale	1	10
Sandstone	1	7
Shale	8	10
Igneous intrusive rock	4	
Shale	2	10
Sandstone	2	8
Igneous intrusive rock	9	6
Shale	10	3
Igneous intrusive rock	14	7½
Sandstone	6	5
Shale	5	11½
Igneous intrusive rock	6	11
Shale	6	3
Coal	1	2
Shale		2
Coal		4
Shale	1	7½
Sandstone	2	6

	Ft.	in.
Shale	15	5½
Sandstone	1	
Shale	21	9
Sandstone	5	2
Shale	8	5
Sandstone	5	6
Shale	7	10
Sandstone	5	7
Shale	1	8
Sandstone	1	
Shale	10	7
Sandstone	1	
Shale	3	10
Sandstone	24	3
Coal	2	7½
Shale	2	10
Coal	1	9½
Shale	4	3
Coal		3
Shale		4
Sandstone	1	11
Shale	1	2½
Coal, shaly		11½
Coal	5	1
Shale	1	½
	384	10½

The occurrence of a valuable bed of coal near the outcrop farther to the east has been shown by the sections described from localities near the junction of Coal and Dillon canyons. A drill hole that tested the character of the coal midway between this junction and the new Dutchman mine was put down at locality P in the west branch of Dillon Canyon, locally known as Wheatcroft Canyon. The main coal bed was 4 feet 2 inches thick and two thin beds were found above it in the Vermejo formation. As suggested in the description of locality 230, the first thin bed above the main coal may represent the upper bench, or the coal above the bony layer in the new Dutchman mine. It may, however, represent the thin coal above the main bed farther west, as the 2-inch coal above the main bed at locality M, and by the 3-inch coal between the two thick beds at locality O. If this correlation is correct the 10½-inch coal at locality P probably corresponds to the lower bench of the upper bed at locality O and the upper bench may have been eroded. This, however, is only a suggestion, for there are no means at present of determining whether the first sandstone above this coal or one of the higher sandstones represents the base of the Raton formation. The rocks penetrated by the drill in Wheatcroft Canyon are as follows:

Section of rocks at locality P, in Wheatcroft Canyon.

[Adapted from a drill record. For graphic section see Pl. XII.]

	Ft.	in
Surface material	8	6
Shale	1	
Coal		6
Igneous intrusive rock	1	4
Sandstone and shale	9	11
Igneous intrusive rock	1	
Sandstone and shale	10	6
Coal	2	2
Igneous intrusive rock		4
Coal		6
Sandstone and shale	35	10
Coal		4
Shale	6	6
Coal, shaly		8
Shale	3	5
Coal		8
Sandstone and shale	21	1
Coal, shaly		7
Sandstone and shale	19	9½
Coal		7½
Sandstone and shale	74	11
Coal		10½
Shale	9	2¾
Coal		10
Shale	1	11
Coal	4	2
Shale		10
Sandstone	21	2
	239	2¼

The character of the main coal bed beneath Dillon Canyon above the mouth of Coal Creek was tested by 5 drill holes and that beneath the floor of Coal Canyon by two. In Dillon Canyon about 2,700 feet above the mouth of Coal Canyon a hole was put down at locality Q. A thick bed of coal was found here, but it consists of three benches of coal interbedded with shale. It differs in character from the bed penetrated in the prospects farther south in that the thickest bench is above the thin ones, as shown in section Q in Plate XII. The rocks penetrated by the drill at this locality are as follows:

Section of rocks at locality Q, in Dillon Canyon.

[Adapted from a drill record. For graphic section see Pl. XII.]

	Ft.	in.
Surface material	20	
Shale	11	
Sandstone	3	
Shale	14	
Sandstone, with bands of shale	27	1

	Ft.	in.
Shale		6
Sandstone	1	6
Shale, with thin seam of coal at base	1	9½
Coal	4	2
Shale	1	11½
Coal	2	½
Shale		8½
Coal	1	1
Shale		8
	89	6

About 2,380 feet farther up Dillon Canyon, at point R, a drill hole was put down 175 feet. The main coal bed was penetrated, but it consists at this locality of two benches of coal separated by a shale parting instead of three benches such as were penetrated at locality Q. The character of the higher beds suggests that the 23-foot sandstone above the coal is the base of the Raton formation and that the upper part of the coal bed was here eroded prior to the deposition of this sandstone.

The following rocks were penetrated by the drill at this locality:

Section of rocks at locality R, in Dillon Canyon.

[Adapted from a drill record. For graphic section see Pl. XII.]

	Ft.	in.
Surface material	20	
Igneous intrusive rock	4	
Sandstone and shale	13	
Coal		6
Sandstone and shale	32	6
Coal		3
Sandstone and shale	11	
Coal		2
Sandstone and shale	63	1
Sandstone	23	8
Coal, shaly		6
Coal	4	4½
Shale		3
Coal	1	2½
Shale		8
	175	2

At a point 1,890 feet farther up the canyon, at locality S, the third drill hole was put down to a depth of 259 feet. The main coal or lowest bed here consists of a single bench, although the upper part is somewhat shaly, but here, as in the prospect farther south at locality O, a second bed occurs above the main coal, although unlike the bed at locality O this higher coal is too shaly to be of much value.

These drill prospects indicate rather clearly that even at these eastern localities the Vermejo thickens toward the west. The fact

that in Vermejo Park, 26 miles to the west, the Vermejo beds are nearly 400 feet thick and are coal-bearing from bottom to top gives grounds for the hope that beds thick enough to be of commercial value may be found in it in the intervening territory at horizons above the Raton bed, although they do not outcrop at the surface farther to the east. This possibility is illustrated graphically in records R, S, and T (Pl. XII). But it is by no means certain that this westward thickening of the coal-bearing beds of the Vermejo formation is more than local, as shown in records M to P, inclusive, on the same plate. Furthermore, the record of the drill hole at locality FF, in Tinpan Canyon, if correctly interpreted, shows an absence there of thick beds of coal in the Vermejo formation.

The rocks penetrated by the drill at locality S are as follows:

Section of rocks at locality S, in Dillon Canyon.

[Adapted from a drill record. For graphic section see Pl. XII.]

	Ft.	in.
Surface material	18	
Sandstone and shale	35	
Igneous intrusive rock and 1 inch of shale	41	
Shale and thin sheets of igneous rock	12	8
Sandstone and shale	127	5
Shale		2
Coal, shaly		5
Coal		6
Shale		4
Coal		8
Shale	2	10
Coal	1	
Sandstone	2	2
Shale	14	6
Coal		8
Coal, shaly		2
Coal	4	5
Shale	1	6
Sandstone		4
	263	3

A drill hole put down at locality T, at the junction of Tinpan and Dillon canyons, penetrated a bed supposed to be the Raton coal bed, but some coke was found in it and much shale.

Section of rocks at locality T, in Dillon Canyon.

[Adapted from a drill record. For graphic section see Pl. XII.]

	Ft.	in.
Surface material	20	
Sandstone	74	3
Sandstone and shale	5	10
Igneous intrusive rock		11

	Ft.	in.
Sandstone and shale	5	8
Coal		3
Sandstone	7	6
Shale	3	8
Sandstone	13	
Coal		3
Shale	1	1
Sandstone	4	6
Shale, sandy	13	6
Shale	1	4
Coal		9
Shale	3	
Sandstone	2	4
Igneous intrusive rock	3	11
Sandstone	5	2
Shale	1	6
Coal, shaly		10
Shale		6
Sandstone	2	10
Shale	3	7
Sandstone	5	7
Shale	1	7
Sandstone	4	
Shale	5	8
Coal		6
Shale	3	11
Coal, shaly	1	2
Shale		5
Coal, shaly		6
Shale	1	5
Coal, shaly		4
Shale	3	9
Sandstone	1	4
Shale	8	3
Sandstone	6	4
Igneous intrusive rock	54	7
Shale	8	10
Sandstone	22	8
Shale	2	6
Sandstone	4	2
Shale	6	2
Sandstone	2	8
Shale	2	3
Sandstone	9	2
Shale	5	10
Sandstone	5	2
Shale	3	7
Sandstone	1	
Shale	3	6
Sandstone	1	9
Shale	7	2
Sandstone	2	5

	Ft.	in.
Shale	7	5
Coal, shaly	2	
Shale		7
Shale, carbonaceous	1	
Coal, shaly	2	1
Shale		6
Sandstone	6	
Shale, carbonaceous		10
Coal, shaly	3	10
Shale	1	9
Sandstone	32	6
Shale	4	10
Sandstone	12	4
	440	

The southern of the two drill holes in Coal Canyon was put down at locality U, about 2,000 feet north of the junction of Coal and Dillon creeks. The drill penetrated both of the benches of the Raton coal which appear in the exposures at the outcrop near the mouth of Coal Canyon. However, both benches seem to become thinner toward the north, and the coal seems to have practically disappeared farther to the north at the second prospect, as described below.

The rocks penetrated by the drill at locality U are as follows:

Section of rocks at locality U, in Coal Canyon.

[Adapted from a drill record. For graphic section see Pl. XII, p. 78.]

	Ft.	in.
Surface material	15	
Sandstone and shale	31	9
Sandstone, massive	8	7
Coal	1	10
Shale	2	9
Coal		11
Shale		6
Coal	2	3
Shale	6	
Sandstone	13	6
Shale	2	
	85	6

In Dillon Canyon the base of the Raton formation is well marked by a sandstone that outcrops above the Raton coal bed. Although there is nothing in the records of the drill prospects in Coal Canyon to indicate where an equivalent of this sandstone may occur, an inspection of the records suggests that it may very probably be represented by the 9-foot sandstone above the coal at locality U. If this be correct the upper bench may originally have been thicker than 1 foot 10 inches and the upper part may have been eroded before the sandstone was formed.

About 2,300 feet farther north, at locality V, a second drill hole was put down in Coal Canyon. It is supposed to have reached a horizon somewhat lower than that of the Raton coal bed, but very little coal was found. The absence of coal of any considerable thickness at the horizon of the Raton bed may be due to a thinning out of the coal beds toward the north; in other words, perhaps no thick bed of coal was ever formed here. If this is true it is a unique condition in the area described in this report. It may be an error of interpretation, however, for throughout this area one or more beds of coal of considerable thickness occur at the horizon of the Raton coal except where the coal has been destroyed by intrusions of igneous rock or was eroded prior to the deposition of the younger rocks. To the writer a more probable explanation of the absence of a thick bed of coal here is that the sandstone that rests on the 10-inch bed of coal is the basal sandstone of the Raton formation and that the main coal bed was eroded prior to the deposition of this sandstone.

The following rocks were penetrated by the drill at this locality:

Section of rocks at locality V, in Coal Canyon.

[Adapted from a drill record.]

	Ft.	in.
Surface material	10	
Sandstone and shale	21	6
Coal		7
Sandstone and shale	17	6
Coal		8
Sandstone and shale	85	5
Sandstone, massive	11	9
Coal		10
Shale with streaks of coal	1	
Sandstone	9	3
	158	6

BLOSSBURG AND GARDINER MINES.

Relatively little information can now be given regarding the Gardner, Blossburg, and Old Dutchman mines, other than that published in annual reports of the mine inspector to the Secretary of the Interior. However, the large area over which the workings were extended indicates that favorable conditions for economic production prevailed there, and the commercial importance of the mine is indicated by the fact that it was once capable of producing 400,000 tons of coal a year.

The physical conditions affecting mining were exceptionally favorable in this region. Except a few thin layers of shale and bone the coal bed as reported is remarkably homogeneous over large areas. In the mine it averaged about 6 feet thick. From a maximum thickness of more than 8 feet in the eastern part the coal decreased

to an average of about 4 feet 5 inches in the western part of the workings.

The general dip of the bed in a westerly direction is so slight—50 to 100 feet to the mile—that mine entries could be driven in any direction desired. Little water was encountered, and although some gas was found it did not seriously interfere with mining operations. The floor shale was rather soft, and according to report a considerable amount of coal was "lost" because of the "creeping" and "heaving" of this shale. However, all things considered this area seems to be admirably adapted to successful mining, and doubtless operations will be renewed here in the future for the purpose of obtaining the large quantity of coal still remaining in the ground.

Mine No. 4, or the part of the old workings west of Dillon Canyon and south of Seeley Canyon is one of the oldest mines in New Mexico and dates from the construction of the portion of the Santa Fe Railway that lies in New Mexico for which it supplied fuel for many years. The first published description of this mine was given in the Mine Inspector's report for 1898. At that time 76 coke ovens of the beehive type were in use, of which the inspector said: "There is a peculiar feature in connection with the ovens, which is quite an innovation in the West." This feature consisted in an arrangement whereby the waste heat from the ovens generated steam for operating an electric plant. The mines were equipped with electric generators, aggregating 500 horsepower and making a 500-volt current. The mining was done with Morgan-Gardiner electric mining machines, and the haulage was by electric locomotives. In the same year,. 1898, a washing plant was in operation. It consisted of two Robinson-Wiggs coal washers, capable of washing 800 tons of coal per day, although only one was in operation at that time. The machinery and all connecting tramways were operated by electric power. The mine was ventilated by electrically driven Guibal fans.

In 1901 mines Nos. 6 and 9 were abandoned and the pillars drawn, and mines Nos. 1, 2, and 3 were equipped to take their place in supplying the market. These are also known as the Dutchman Canyon, Dillon Canyon, and Wheatcroft Canyon mines. The Dillon Canyon mine opens in the east wall of Dillon Canyon at the mouth of Coal Creek. It was operated by the Santa Fe Railway Co. in 1880 and consisted of two main entries 1,000 feet apart, which were driven in about 800 feet on the bed. Apparently this mine was not operated long. No. 4 mine, or the workings south of Dutchman Canyon, was closed December 1, 1902.

A meager record of the character of the coal west of Dillon Canyon has been preserved in the reports of Orestes St. John to the Raton Coal & Coke Co. He gives the following analysis, made at the

Colorado School of Mines, as representative of the coal of the Blossburg mine:

Analysis of coal from Blossburg mine.

[Colorado School of Mines, analyst.]

Moisture	1.23
Volatile matter	37.28
Fixed carbon	56.01
Ash	5.48
Sulphur content low.	

The other samples of coal from this mine were collected in the extension west of Gardiner, one in the fourteenth left entry, about 500 feet south of the westermost point of outcrop in the north fork of Gardiner Canyon, and the other in the sixteenth left entry, about 1,000 feet south of this outcrop. They were analyzed at the St. Louis Smelting & Testing Works under the supervision of William B. Potter, who reported as follows:

Analyses of coal from Gardiner extension of Blossburg mine.

[William B. Potter, analyst.]

	1	2
Moisture	1.39	1.28
Volatile matter	32.46	33.90
Fixed carbon	54.88	56.68
Sulphur	.62	.65
Ash	10.65	7.49
	100.00	100.00
British thermal units	12,513	12,948

1. Sample from fourteenth left entry.
2. Sample from sixteenth left entry.

Equal parts of these samples were treated in coke ovens, and 67 per cent of coke was obtained, a sample of which was analyzed with the following result:

Analysis of coke made from Blossburg coal.

[William B. Potter, analyst.]

Moisture	0.26
Volatile matter	.79
Fixed carbon	82.87
Sulphur	.42
Ash	15.66
	100.00

Mr. Potter says:

As will be seen by the samples of this coke sent it is hard and strong, and the composition as shown above is very good, although the ash is of course higher than the best of cokes. The sulphur, on the other hand, is remarkably low.

A practical smelting test was made at Bisbee, Ariz., by the Copper Queen Consolidated Mining Co. with coke made from the Blossburg

coal at the ovens at Starkville, Colo. The furnace was run 63 hours with this coke and the results compared with a 3 days' run with Starkville and Cerrillos coke. Mr. Ben. Williams, the superintendent, reported very little difference in the results. In his report he includes the following analyses of the coke used:

Analyses of coke used in smelting tests.

	1	2
Volatile matter	0.25	0.05
Fixed carbon	79.89	79.69
Ash	19.30	19.85
Sulphur	.56	.41

1. Blossburg coke.
2. Starkville and Cerrillos coke.

NEW DUTCHMAN MINE.

The "new" Dutchman mine, now abandoned, north of Dutchman Canyon, was inaccessible at the time of the writer's investigation. Information concerning it was furnished by Mr. F. A. Young, the engineer in charge, and the mine maps and charts and the published reports of the mine inspector gave additional information. The mine was opened in 1898 and was operated until October 5, 1906, when it was closed on account of a disastrous explosion. Although it has not been reopened since that time, it probably will be operated again, and therefore the following details concerning it are given.

The mine is west of Blossburg and north of Dutchman Canyon, on a spur of the Atchison, Topeka & Santa Fe Railway that connects with the main line at Dillon. The mine opens in Dutchman Canyon, and the entry is driven down the dip under a cover of more than 500 feet of rock. The roof of the mine consists mainly of shale but in some places of sandstone. The roof is moderately strong and generally holds up well, although in some places the material disintegrates on exposure and falls in plates. No "draw slate" was regularly taken down, and the upper part of the coal was left in places to serve as a roof. The entries were timbered with props and crossbars, and the rooms with props and caps. The roof shale is smooth and separates readily from the coal. This shale yielded some gas, especially where there are beds of coal above it. There are many rolls, but no horsebacks or other irregularities have been found. Major joints a few inches apart are well developed, the cleat faces running parallel with the dip of the bed in a direction a few degrees north of west. Minor joints are also well developed. The floor consists of soft gray shale 1 to 5 feet thick and is free from inclusions of coal.

The entrance to the mine was by timbered double compartment slope, each compartment 6 by 10 feet in cross section. The system of mining was by room and pillar. The mine was ventilated by a

24-foot Guibal fan having a capacity of 65,000 cubic feet a minute, run by an independent engine. The distribution of air was by the splitting method, and the draft was regulated and directed by doors, overcasts, and break-throughs, the latter 100 feet apart. Some gas was encountered in the mine and was a source of some trouble. An explosion occurred June 19, 1903. However, open lights were still used, and it is supposed that gas caused the explosion that finally wrecked the mine on October 5, 1906.

The mine was relatively wet and was drained by two electric pumps, each having a capacity of 100 gallons a minute. They were run by a 550-volt 75-horsepower Card generator, which also supplied current for lighting the mine. The electric haulage system and cutting machines that had been used in the older mines were not used in this mine.

The coal was undercut by hand, an incision 10 inches high and 3 feet deep being made at the bottom of the bed, and the coal was shot down with black powder. Post drills were used. No shot firers were employed. The mine haulage was by mules. The coal is black, bituminous, and relatively hard and varies in purity from bone-free coal to coal that is too bony to be of commercial value. Coal from this mine was collected for analysis and for other tests by the United States Geological Survey fuel-testing plant, and the results are given below.[11] For convenience of reference the designations are left unchanged in the following descriptions:

Bituminous coal from Blossburg, Colfax County, on the Atchison, Topeka & Santa Fe Railway, was designated New Mexico No. 5. The coal as worked from the outcrop at this place averages 7 feet 6 inches in thickness.

This sample, which was run-of-mine coal, was used in making steaming test 387, producer-gas test 120, washing test 167, coking tests 146 (raw) and 147 (washed), and cupola test 120, quoted below. A portion mixed with New Mexico No. 3-B and No. 4-B (equal portions, washed) was used in coking test 152 and cupola tests 98 and 130.[12] For the composition of this sample see anaylsis 3294 in the table on page 242.

Steaming test 387 of New Mexico No. 5 (run of mine).

Size as used:		
Over 1 inch	per cent..	21.2
$\frac{1}{2}$ inch to 1 inch	do....	19.9
$\frac{1}{4}$ to $\frac{1}{2}$ inch	do....	20.8
Under $\frac{1}{4}$ inch	do....	38.1
Duration of test	hours..	10.07
Heating value of coal	B. t. u. per pound dry coal..	12,721
Force of draft:		
Under stack damper	inch water..	0.58
Above fire	do....	.21
Furnace temperature	°F..	2,371
Dry coal used per square foot of grate surface per hour	pounds..	21.11

[11] U. S. Geol. Survey Bull. 332, pp. 184-187, 1908.

[12] Op. cit., pp. 179, 180.

Equivalent water evaporated per square foot of water-heating surface per hour .... pounds..	3.54
Percentage of rated horsepower of boiler developed	99.13
Water apparently evaporated per pound of coal as fired . pounds..	7.0
Water evaporated from and at 212° F.:	
Per pound of coal as fired .... do....	8.19
Per pound of dry coal .... do....	8.39
Per pound of combustible .... do....	10.23
Efficiency of boiler, including grate .... per cent..	63.69
Coal as fired:	
Per indicated horsepower hour .... pounds..	3.45
Per electrical horsepower hour .... do....	4.26
Dry coal:	
Per indicated horsepower hour .... do....	3.37
Per electrical horsepower hour .... do....	4.16

Producer-gas test of New Mexico No. 5 (run of mine).

Test 120.—Duration of test, 45 hours. Average electrical horsepower, 197.2. Average B. t. u. per cubic foot of gas, 159.6. Total coal fired, 12,500 pounds.

	Coal as fired.	Dry coal.	Combustible.
COAL CONSUMED IN PRODUCER PER HORSEPOWER HOUR (POUNDS).			
Per electrical horsepower:			
Commercially available	1.49	1.47	1.24
Developed at switchboard	1.41	1.38	1.17
Per brake horsepower:			
Commercially available	1.27	1.25	1.05
Developed at engine	1.20	1.18	.99
EQUIVALENT USED BY PRODUCER PLANT (POUNDS).			
Per electrical horsepower:			
ommercially available	1.60	1.57	1.33
Developed at switchboard	1.51	1.48	1.25
Per brake horsepower:			
Commercially available	1.36	1.34	1.13
Developed at engine	1.29	1.26	1.06

Analyses of coal and gas, producer-gas test 120.

Coal.

Moisture	1.79
Volatile matter	31.32
Fixed carbon	51.40
Ash	15.49
Sulphur	.66

Gas by volume.

Carbon dioxide (CO_2)	8.6
Carbon monoxide (CO)	21.4
Hydrogen (H_2)	14.6
Methane (CH_4)	2.2
Nitrogen (H_2)	52.7
Ethylene (C_2H_4)	.5

Washing and coking tests of New Mexico No. 5 (run of mine).

Washing test 167.—Size as used, crushed to 2 inches; jig used, Stewart; raw coal, 15,000 pounds; washed coal, 13,300 pounds; refuse, 1,700 pounds.

Coking tests.

		Test 146 (raw).	Test 147 (washed).
Size as used		finely crushed.	finely crushed.
Duration of test	hours	56	50
Coal charged	pounds	11,810	11,770
Coke produced	do	7,500	7,650
	per cent	63.51	65.00
Breeze produced	pounds	320	280
	per cent	2.71	2.38
Total yield	do	66.22	67.38

Remarks.—Test 146: Light gray color; good heavy coke; high ash. Test 147: Light gray and silvery; good heavy coke; ash reduced by washing, but still high.

Analyses.

	Washing test 167.		Coking test 146.		Coking test 147.	
	Raw coal.	Washed coal.	Coal.	Coke.	Coal.	Coke.
Moisture	2.72	4.68	3.05	1.04	4.23	0.99
Volatile matter	31.85	....	31.96	1.44	32.25	.84
Fixed carbon	50.86	....	49.71	76.93	51.79	81.38
Ash	14.57	11.87	15.28	20.59	11.73	16.79
Sulphur	.69	.91	.76	.86	.89	.76

Cupola test of coke made from New Mexico No. 5 coal (washed).

Charge.

Cupola test No.	Coke.[a]			Fluidity strip full.	Materials.	Divisions of charge.					Total.
	Test No.	Specific gravity.	Ratio iron to coke.			1	2	3	4	5	
				Per ct.		*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
120	147	1.91	7	99.9	Coke	220	53	53	52	52	430
					Pig iron	660	398	398	397	397	2,250
					Scrap	220	133	133	132	132	750

a Phosphorus in coke, 0.001 per cent.

Record of melt.

Cupola test No.	Blast pressure.		Iron running in—	Weight of iron.			Melting.				Recovered.	
	On at—	Maximum.		Poured.	Additional melted.	Total.	Time.	Rate per hour.	Ratio iron to coke.	Loss.	Iron.	Coke.
		Oz.	*Min.*	*Lbs.*	*Lbs.*	*Lbs.*	*Min.*	*Lbs.*		*Per ct.*	*Lbs.*	*Lbs.*
120	2.17 p. m.	7	10	1,354	124	1,478	28	3,167	4.58	7.40	1,300	107

Cupola test of coke made from New Mexico No. 5 coal (washed)—Continued.

Ladle record.

Ladle No.	Test 120.		Ladle No.	Test 120.	
	Pounds.	Time (p. m.).		Pounds.	Time (p. m.).
1	93	2.34	10	99	2.43½
2	50	2.34½	11	96	2.44½
3	57	2.39	12	101	2.47
4	107	2.39½	13	90	2.48
5	99	2.40	14	56	2.47
6	43	2.40½	15	92	2.52½
7	83	2.41	16	32	2.53
8	92	2.42	17	69	2.55
9	95	2.43			

Remarks.—Test 120: Iron hot and fluid.

Two mine samples of the coal were collected for analysis on May 10, 1906, by J. W. Groves. Sample 3226 came from room 6, off fifth north entry, near locality 282, and sample 3227 from room 1 off the second subentry, near locality 278. The results of the analyses are given on page 242. The sections at these localities measured as follows:

Section of coal bed in new Dutchman mine near Blossburg.[a]

	Laboratory No. 3226.		Laboratory No. 3227.	
	Ft.	*in.*	*Ft.*	*in.*
Coal, bony.				
Coal	1	3½	[b] 1	10¼
Shale		[b] ½		[b]
Coal		[b] 3	[b] 2	9
Bone		[b] ¼		1
Coal		[b] 2	[b] 2	
Bone and shale		[b] ¼		½
Coal	[b] 1	2		[b] 5
Coal, bony		1½		¾
Coal	[b] 3	10		[b] 6
Shale.				
Thickness of bed	6	11	7	8½
Thickness of bed sampled	5	6	6	6¼

[a] Bur. Mines Bull. 22, p. 639, 1913. [b] Included in sample.

SWASTIKA MINE.

The Swastika mine is really a northward extension of the new Dutchman mine and was being developed at the time of the writer's last visit to the region, in 1919. The coal bed exposed at that time does not differ materially from that described in the new Dutchman mine.

NEW GARDINER MINE.

The new Gardiner mine was opened in 1911, but prior to the summer of 1913, when the writer examined it, had not been operated as actively as some of the other mines in the Raton field. It is east of Dillon Canyon and opens in the canyon wall south of Coxe Canyon about 300 feet above the bed of the stream. The coal developed in this mine lies above the prominent cliff-making Trinidad sandstone

and below a less prominent sandstone that constitutes the base of the Raton formation. It is the highest commercially valuable bed in the Vermejo formation in this vicinity and probably corresponds to the higher of the two beds of coal described from localities west of Dillon Canyon.

The roof of the mine consists of shale in most places, but in some places the sandstone, which lies unconformably on the Vermejo beds and which at the mouth of the mine is 8 feet above the top of the coal bed, rests on the coal and forms the roof of the mine. The roof shale is regular in character and has many "pots" and slips that make it insecure in some places.

The coal is relatively hard and tough like all the Vermejo coals of the Raton field. Its somewhat banded appearance is due to alternating laminae of coal that differs slightly in character. Some of the thin layers consist of coal that is bright, vitreous, and brittle; others of dull lusterless coal or charcoal that is more or less porous; and still others consist of coal that seems to be somewhat bony. The coal is a coking coal, and the finer material from the mine is washed and coked in the ovens at Gardiner. The coal does not slack readily on exposure to the weather and is shipped without notable deterioration.

The character of the coal bed in this mine is shown graphically in Plate XI (p. 78). In room 6 of the first cross entry west of the main at locality 283 the coal is 5 feet 5 inches thick and has 6 inches of bone at the top. Both roof and floor are shale. On September 27, 1912, the writer collected in this room for analysis a sample of the coal exclusive of the bone. The results are given as analysis 14795 in the table on page 242.

West of this locality the coal thickens to 6 feet, and in the main entry at locality 284 the bed consists of 6 feet 9 inches of coal with shale above and below it. A few feet northeast of this locality a 3-foot dike crosses the main entry in a direction N. 80° W. It was encountered also in the rooms to the east and is probably the same as the dike observed at the surface near the mouth of Coxe Canyon and in several places to the east as far as Raton. The coal thins somewhat to the northeast, being 6 feet at locality 285 and 6 feet 2 inches at locality 286. Between these localities the bed is disturbed by a dike and two faults. Both the dike and faults lie parallel with the 3-foot dike just described. The faults bound a segment about 100 feet across that has dropped 6 feet.

Toward the south the beds maintain a uniform thickness for some distance. The thickness is 6 feet 6 inches at locality 287, but farther south a parting of bone occurs in the middle of the bed at locality 288 and develops toward the south into a definite layer an inch

thick at locality 289. This bony parting increases in thickness to the east, and at locality 290, at the end of the entry 400 feet from locality 289, it becomes a layer of shale 2 feet thick.

The new Gardiner is a double entry drift mine operated on the room-and-pillar plan. The main entry is driven northeastward in a direction normal to the cleat faces and the cross entries are driven on the butts. The principal entries are illuminated by electric lights, but open lights are used in the rooms. No gas has been encountered. Ventilation is accomplished by means of an electrically driven exhaust fan.

The coal is undercut by hand and shot from the solid by shot firers, who operate only at night, when other workmen are out of the mine. The cleat faces, although fairly well developed in some places, have not proved to be of much use in mining. Mules are used for hauling the cars in the mine, but the coal is lowered to the tipple over a gravity incline and is there passed over a bar screen that separates it into lump and "slack." The lump is used mainly on railway locomotives, and the "slack" is coked at the Gardiner plant, where 210 beehive ovens were in operation at the time of investigation. (See Pl. IX, *A*, p. 48.)

DAWSON DISTRICT.

LOCATION.

The Dawson district lies chiefly west of the Koehler quadrangle, although the workings of the Dawson mine enter this quadrangle to some extent. The accompanying sketch map (Pl. XIII) shows its areal relationships.

The commercial center of the district is the town of Dawson, in Vermejo Canyon at the mouth of Rail Canyon, where the mine offices are situated. The coal bed in which the several mines of the Dawson group are developed crops out in the walls of these canyons.

GEOLOGIC RELATIONS.

All the sedimentary formations exposed near Dawson, which are the same as those of the other districts of the Raton coal field described in this bulletin, dip toward the northwest. The dip is slightly irregular, both in degree and in direction, but the general dip, as determined in the mine entries, is about 50 feet to the mile. The mine is more than ordinarily free from faults, and warping of the beds has occurred in but few places. The most notable warping yet found is in the main entry of mine No. 3, where the altitude of the coal changes 40 feet in a horizontal distance of 100 feet. The absence of notable disturbance of rock in the mines may be due to the occurrence of the coal between two resistant sandstones, the

Trinidad below and the Rail Canyon sandstone member of the Vermejo formation above.

The exposed sedimentary formations, in order from oldest to youngest, are as follows:

The Pierre shale is exposed in the lower slopes in the eastern part of the district. It is soft and weathers to a relatively smooth surface. Owing to the general westward dip of the formations, this shale disappears to the west under younger rocks. It is of marine origin, and the shells of many sea animals may be found in it. Although it is dark no coal is likely to be found in it.

The Trinidad sandstone overlies the Pierre shale conformably and forms conspicuous light-colored cliffs. Like the underlying shale it is of marine origin, and shells of sea animals are found in it at some places. It represents the last stage of the filling of the sea, and in some places carbonaceous shale and thin beds of coal are found in it, but in no place are the coal beds thick enough to have economic value.

The Vermejo formation lies conformably on the Trinidad sandstone. It consists of coal, shale, and sandstone. The line of contact between it and the Trinidad sandstone is usually definite, but in some places it can not be drawn with confidence. However, the Trinidad-Vermejo contact, which represents an ancient sea level, constitutes the best means available for exact correlation of sections; hence, the Trinidad is used in Plate XIV as the horizontal base on which the columnar sections rest.

The Vermejo formation is nonmarine. It consists of material which accumulated on the old coastal plain from which the sea had been expelled, probably by the accumulating sediments, the last of which was the sand of the Trinidad sandstone. On this plain developed the swamps in which material accumulated for the coal beds of the Vermejo formation.

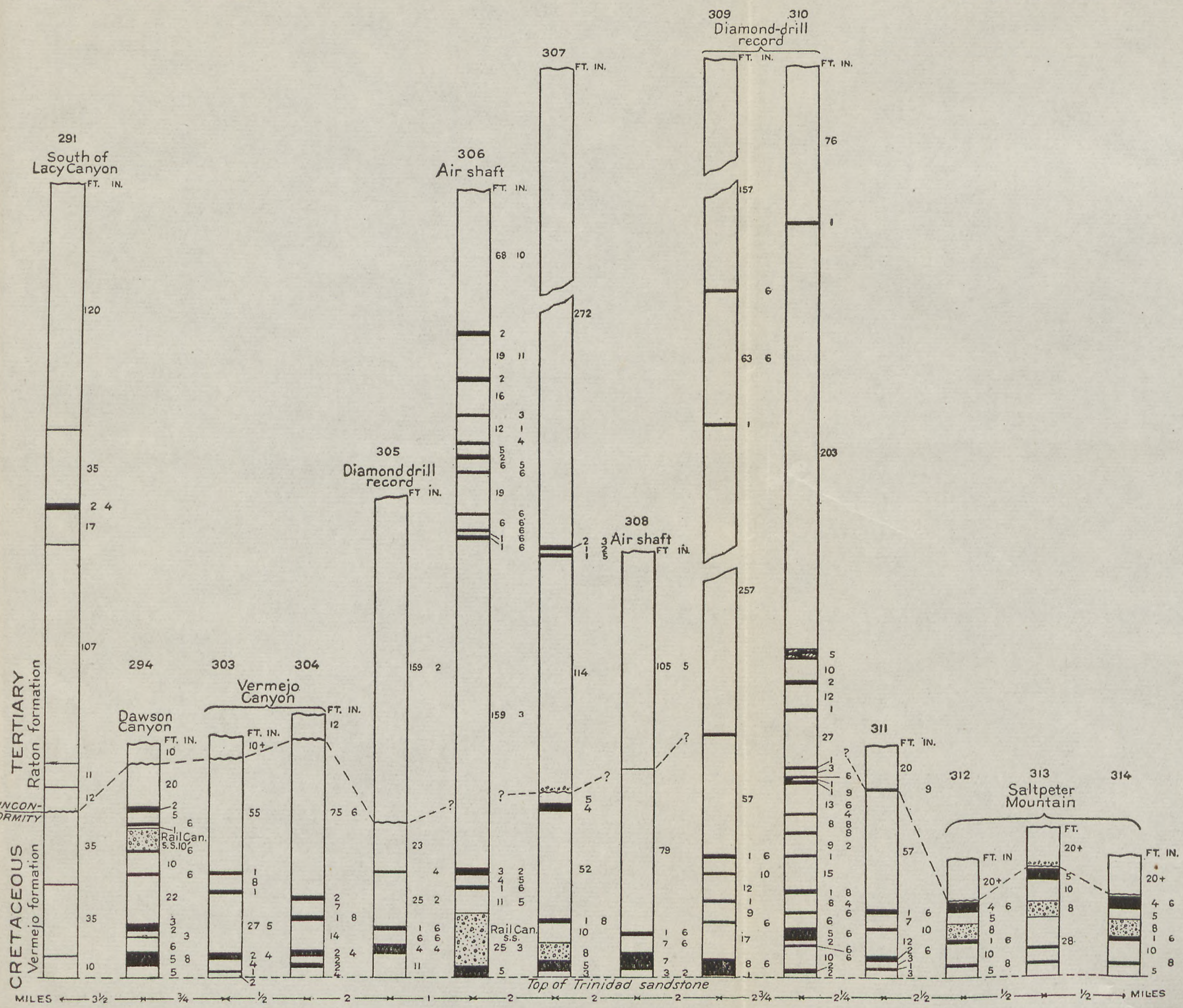
In most places throughout the Raton coal field the Vermejo is regular in lithologic character, consisting of coal, shale, and thin beds of sandstone, but near Dawson there is a notable exception to this general rule. There is a peculiar sandstone near the middle of the formation which lies unconformably on the beds below it. It is a massive cross-bedded sandstone ranging in thickness from a few feet to 40 or 50 feet. It is readily recognized by its numerous inclusions of clay balls, which have the appearance of originating as clay pebbles, such as are sometimes found where a clay bank is undercut by a stream or by waves. This sandstone forms the roof of the mines in many places throughout the Dawson district; hence its relation to the underlying beds is well known. For example, at locality 294, near mine No. 8, it is about 44 feet above the main coal bed, whereas in mine No. 7, only a few hundred feet from locality 294, this sand-

SKETCH MAP OF THE DAWSON COAL DISTRICT, N. MEX.

Showing mine workings and localities where sections were measured

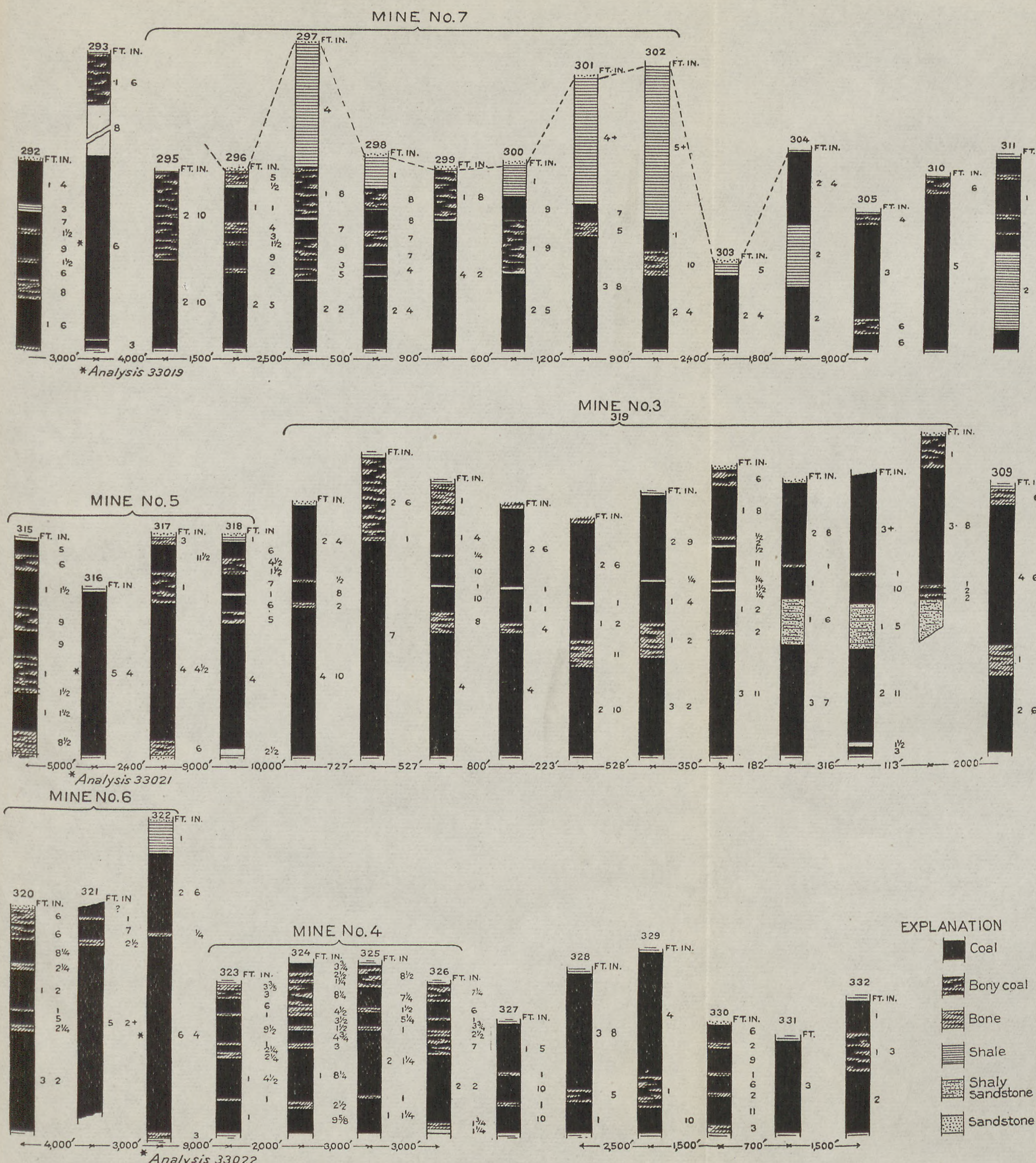
Scale $\frac{1}{62,500}$

0 1/2 1 2 3 4 5 Miles



SECTIONS OF COAL-BEARING ROCKS IN THE DAWSON COAL DISTRICT.

Measured at the outcrop and in air shafts and drill holes. Numbers over the sections correspond to locality numbers on Plate XIII.



SECTIONS OF THE COAL BED IN THE DAWSON DISTRICT.

Measured at the outcrop and in the mines. Numbers over the sections correspond to locality numbers on Plate XIII.

stone rests directly on the main coal. Throughout the mined area northeast of Vermejo Canyon it forms the roof of the mines in many places, but in other places shale and thin beds of coal intervene between it and the main coal bed. The thickness of these intervening beds can be determined only in places where for some special reason they have been penetrated in mining or prospecting. The relation of the sandstone to the main coal bed is indicated in a measure in the graphic sections of the main coal bed. (See Pl. XIV.) This sandstone extends to the southern extremity of the Dawson district, but its relations to other beds south of this district are not known. It extends northward as far as drill tests have been made. It is recognizable on Saltpeter Mountain and thence northward as far as the head of Five Dollar Canyon.

It is obvious from the observed relations that in mid-Vermejo time local erosion occurred near Dawson, perhaps along a stream which flowed across the old coastal plain. This erosion removed some of the previously formed beds of shale and coal. Later sand and clay

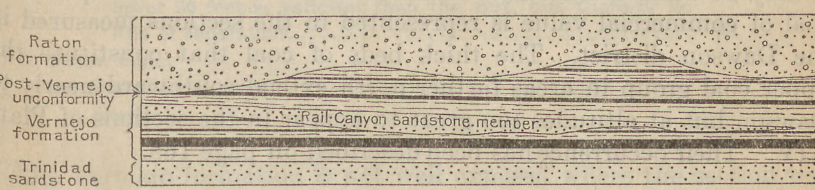


FIGURE 9.—Sketch profile through Dawson mine, showing relations of the Rail Canyon sandstone to beds above and below it. The lower beds of the Vermejo formation were eroded and the Rail Canyon sandstone was deposited on the eroded surface. This sandstone was then covered by the younger beds of the Vermejo, and the later erosion of these younger beds is shown by the post-Vermejo unconformity. On this later eroded surface were deposited the sediments of the Raton formation.

pebbles accumulated on the eroded area to form the peculiar sandstone just described. This sandstone is sufficiently different from the other rocks of the district to warrant the application of a special name. Because of its economic importance in making a firm roof in the Dawson mines in Rail Canyon, it is here named the Rail Canyon sandstone member of the Vermejo formation. (See fig. 9.)

Because of the obvious erosional unconformity at the base of the Rail Canyon sandstone, it should possibly be included in the Raton formation. On the other hand, its lithology is quite different from that observed in the basal sandstone of the Raton formation at any locality where the Vermejo and Raton formations are plainly separable. Furthermore, in many places coal-bearing shale and sandstone similar to those below the Rail Canyon sandstone occur above this sandstone and unconformably below the conglomeratic sandstone here regarded as the base of the Raton formation.

The erosion that made the post-Vermejo unconformity removed parts of the beds previously formed. In some places nearly all of

the Vermejo beds deposited on the Rail Canyon sandstone were removed by this post-Vermejo erosion, so that a thickness of only a few feet of rock now occurs between this sandstone and the base of the Raton formation, as on Saltpeter Mountain. (See sections 312, 313, and 314, Pl. XIV.) In other places the intervening beds are much thicker—about 60 feet in section 307 and nearly 100 feet in sections 309 and 310, if these sections are interpreted correctly.

The removal of parts of the Vermejo beds by erosion represented by the two unconformities explains in large measure, if not wholly, the difference in the number of coal beds from place to place as shown in Plate XIV, which would otherwise be difficult to explain. Though the several beds of coal can not be accurately mapped at present, the relationship is shown by diagram.

The youngest formation near Dawson is the Raton formation, which rests unconformably on the Vermejo, and the sandstone at its base is conglomeratic in some places. This formation has little economic importance near Dawson, although the coal beds high in section A may be utilized some time in the future. With this exception no coal of commercial value is represented in the sections measured in the Dawson district. The thick beds of coal that constitute the upper coal group in areas farther north extend southward nearly to Dawson but at altitudes too great to appear in the sections of Plate XIV. Their occurrence has been described on page 168.

SECTIONS MEASURED AT OUTCROP.

Several sections measured at the outcrop, three logs of drill holes, and two logs of mine shafts give fairly accurate data regarding the geologic relations of the coal beds. These records are given below in order from the south along the outcrop of the coal beds westward and northward and have been used in platting the sections shown in Plate XIV in order from left to right. The dotted lines between the columns in this plate indicate the correlation of the beds and their continuity from place to place.

The first or southernmost section was measured at locality 291 on the spur north of Old Man Dawson Canyon, 3 miles south of Dawson. The Vermejo formation is not well exposed here, but a bed of coal that lies high in the section may be of commercial value when the more easily obtained coal of the lower beds is exhausted. This bed was seen in the north wall of Lacy Canyon and is probably the same as the highest bed of section 307, shown in Plate XIV.

The section measured at locality 291 is as follows:

Section of rocks at locality 291, about 3 miles south of Dawson.

	Ft.	in.
Raton formation:		
Sandstone, yellow, massive	120	
Covered	35	
Coal	2	4
Shale, sandy, not continuously exposed	17	
Sandstone, with partings of shale	107	
Sandstone, yellow, shaly	11	
Sandstone, coarse grained, massive quartzose	12	
	304	4
Probable unconformity.		
Vermejo formation:		
Shale, yellow, sandy; not continuously exposed	35	
Sandstone, white, massive, granular (Rail Canyon sandstone).	35	
Covered	10	
	80	
Trinidad sandstone:		
Sandstone containing *Halymenites major* Lesquereux; the lower 20 feet is yellower than the rest, but there is no line of separation	95	
Pierre shale:		
Transitional zone.		
Shale.		
	479	4

The Vermejo formation is not well exposed where the section was measured at locality 291, but in Dawson Canyon a recent landslide has cleared the loose surface material from this part of the section and left the rocks well exposed. The section measured here supplements that measured at locality 291 in giving the details of the principal coal-bearing formation. This section is as follows:

Section in Dawson Canyon at locality 294, near the opening of mine No. 7.

	Ft.	in.
Raton formation:		
Sandstone and shale not well exposed, several hundred feet.		
Sandstone, coarse, irregularly bedded and massive; contains flinty layers in some places; probably base of Raton formation	10	
Vermejo formation:		
Sandstone and shale	15	
Shale	5	
Coal	1	6
Coal, bony		6
Sandstone and shale	5	
Coal		6
Shale	1	
Sandstone, white, friable, with pebble-like masses of clay.		

Vermejo formation—Continued.	Ft.	in.
Rail Canyon sandstone	10	
Coal		6
Sandstone and shale	10	
Coal		6
Shale	5	
Shale, with thin seams of coal	3	
Shale	14	
Coal	3	
Shale	2	
Coal		3
Shale	6±	
Coal, bony	2	10
Coal	2	10
Shale	5	
Trinidad sandstone.		

Two sections were measured in the south wall of Vermejo Canyon—one at locality 303, at which the rocks of the Vermejo formation are well exposed in a westward bend where the river impinges sharply against the side of the canyon, the second at locality 304, in a spur between the main canyon and a small tributary at Laretto. The sections are as follows:

Section of rocks at locality 303, in south wall of Vermejo Canyon, about 1 mile northwest of Dawson.

	Ft.	in.
Raton formation:		
Sandstone, coarse grained, quartzose, locally conglomeratic	10+	
Unconformity.		
Vermejo formation:		
Shale, with thin beds of coal, not continuously exposed	38	
Sandstone, yellow, massive	12	
Shale, drab	5	
Coal	1	
Shale, drab to black	2	
Sandstone, yellowish white, massive, friable	6	
Coal	1	
Shale	4	
Sandstone, white, massive, friable	23	
Shale, black		5
Coal	2	4
Shale	4	
Coal	1	
Shale, black, carbonaceous	2	
	101	9
Trinidad sandstone:		
Sandstone, containing *Halymenites major* Lesquereux	70+	
	181+	

Section of rocks at locality 304, about 2 miles northwest of Dawson.

	Ft.	in.
Raton formation:		
Sandstone, massive, quartzose; locally conglomeratic	12	
Unconformity.		
Vermejo formation:		
Shale and sandstone, not continuously exposed; 2 inches of coal near the top	37	
Shale, with thin layers of sandstone	15	
Sandstone, white, granular	23	
Shale		6
Coal	2	
Shale	7	
Coal	1	8
Shale, with thin beds of sandstone	14	
Coal	2	
Shale	2	
Coal	2	
Shale	4	
Trinidad sandstone.		
	110	6
	122	6

About half a mile upstream from locality 309 the outcrop of the coal bed crosses the river. The presence of coal farther north has been tested by the diamond drill in four places, as indicated on the sketch map (Pl. XIII), but only one of the records was obtained. The boring for which the record is given was made 2 miles north of mines Nos. 5 and 6, at a place which seems to correspond with locality 305. Nothing was learned of the other three drill prospects near this locality. The record obtained is as follows:

Record of diamond-drill boring probably at locality 305, in Vermejo Canyon, about 4 miles northwest of Dawson.

	Ft.	in.
Raton formation:		
Surface débris	14	
Shale	2	
Shale, sandy, and ironstone	5	
Sandstone, white	8	
Shale, gray	18	
Shale, sandy	2	
Sandstone	3	
Ironstone	2	
Sandstone	7	
Ironstone		3
Sandstone, gray, with hard ironstone concretions	5	9
Ironstone	5	2
Shale, gray, soft	29	
Sandstone, gray	7	
Ironstone, green	1	
Shale, drab, sandy	12	
Sandstone, gray, dark pebbles in the central part	14	

	Ft.	in.
Raton formation—Continued.		
Ironstone		6
Sandstone, hard, containing black pebbles	2	6
Ironstone		9
Sandstone, drab, shaly	4	3
Sandstone, gray, coarse grained, with streaks of black ironstone and gray shale; contains pebbles and particles of coal near the base	16	
	159	2
Vermejo formation:		
Sandstone, gray, fine grained	16	
Shale, drab, black at base	7	
Coal		4
Shale, drab	1	8
Shale with ironstones	20	
Sandstone, gray	3	6
Coal	1	6
Shale	6	8
Coal; bony in some places	4	4
Shale, sandy, with ironstone concretions	11	
Trinidad sandstone (?):		
Sandstone, gray	20	
	92	
	251	2

An air shaft for the ventilation of mine No. 5 was cut at locality 306, 1 mile east of locality 305, during 1918. The record of this shaft is given below:

Section measured at locality 306, in air shaft of mine No. 6.

	Ft.	in.
Shale	17	7
Shale, carbonaceous	2	9
Sandstone	3	9
Shale, carbonaceous		6
Sandstone	2	
Shale	1	
Shale, "bony"	41	3
Coal		6
Shale	1	
Coal		6
"Slate, bony"	13	5
Shale	6	6
Coal		6
Shale	1	
Coal		6
"Slate"		6
Sandstone	15	6
Coal		3
Shale	1	9

	Ft.	in.
Sandstone	10	4
Coal		4
Shale, bony	5	
Coal	2	
Shale	6	5
Coal		6
Shale	6	9
Sandstone	12	3
Coal		6
Shale	6	6
Coal		6
Shale	4	6
Coal	4	6
Shale	4	8
Sandstone	21	11
Shale	33	6
Sandstone	26	5
Shale	12	6
Sandstone	34	2
Shale	26	5
Sandstone	29	8
Coal, bony		3
Coal	2	11
Shale, "bony"	4	5
Coal	1	6
Shale, "bony"	11	5
Sandstone (Rail Canyon)	25	3
Coal (Raton bed)	5	
	407	10

A section was measured in the north wall of Vermejo Canyon at locality 307, on the prominent spur northwest of Dawson. The 5-foot coal bed of this section is the one mined. It is overlain by the Rail Canyon sandstone above which is the higher bed of coal sampled at locality 306. Another bed, 4 feet thick, consisting of two benches of coal separated by shale, occurs 52 feet above this higher bed, which was sampled. This higher bed seems to be absent from neighboring sections except at localities 299 and 298, and possibly at locality 301. At other localities it seems to have been eroded prior to the deposition of the Raton formation.

A still higher bed of shaly coal occurs here at about the same horizon as that at locality 291. In Rail Canyon this bed consists chiefly of carbonaceous shale and has not been recognized farther east.

Section of rocks at locality 307, in north wall of Vermejo Canyon, about 1 mile northwest of Dawson.

	Ft.	in.
Raton formation:		
Sandstone, coarse, massive, cliff-making	125	
Sandstone, shaly	20	
Sandstone, massive	35	
Shale, black, with thin seams of coal	6	
Shale and shaly sandstone	16	
Sandstone, massive, cliff-making	10	
Shale, with thin seams of coal	60	
Coal	2	3
Shale	1	2
Coal	1	5
Shale, carbonaceous in some places; contains thin beds of impure sandstone	75	
Sandstone, massive, cross-bedded	8	
Shale, with sandstone nodules	8	
Sandstone, irregular, mainly soft, friable; surface weathers cavernous	18	
Sandstone, conglomeratic	5±	
	390±	
Unconformity.		
Vermejo formation:		
Shale, buff-colored	5	
Coal	4	
Sandstone, white, friable, with thin beds of shale	17	
Shale, black, carbonaceous	1	
Shale, buff-colored	14	
Sandstone, white, friable	5	
Sandstone and shale, buff-colored	12	
Shale, buff-colored	5	
Coal	1	8
Shale and sandstone	10	
Sandstone, white, granular (Rail Canyon sandstone)	18	
Coal	5	
Shale, buff-colored	3	
Trinidad sandstone.		
	90	8
	481±	

An air shaft was sunk several years ago in Rail Canyon at locality 308 for the purpose of ventilating the mine workings beneath. It was started a little below the horizon of the carbonaceous bed just described. There is nothing in the record to indicate the top of the Vermejo formation, and the subdivision of the following record is made on the basis of the change in lithology. It is significant, however, that the 4-foot coal bed of locality 307 was not found. Only two coal beds were encountered in this shaft, whereas six were penetrated by the drill at locality 309. The inference drawn from

the change in lithology may be erroneous, and the Raton formation may include some of the 79 feet here placed as possible Vermejo. If this explanation is true several of the coal beds of localities 309 and 310 were eroded before the Raton formation was laid down.

The record of this air shaft is as follows:

Section of rocks penetrated by an air shaft for Dawson mine No. 2, at locality 308, in Rail Canyon near Dawson.

	Ft.	in.
Raton formation:		
Surface débris	9	
Sandstone, gray to yellow	14	6
Shale, black	9	7
Sandstone, white	3	4
Shale, gray	19	3
Sandstone, yellow	13	8
Shale, black, with ironstone	14	10
Sandstone, white, hard	21	3
	105	5
Vermejo formation (?):		
Shale, gray	4	
Sandstone, red	6	5
Shale, gray, sandy	19	1
Sandstone, gray, hard	11	
Shale, gray, sandy	5	7
Sandstone, light-colored	33	6
Bone	1	6
Shale, gray	7	6
Bony coal	1	
Coal, mined	6	
	95	7
	201	

A diamond drill was put down at locality 309, on the divide between Rail Canyon and Saltpeter Canyon for the purpose of testing the character of the coal beds in advance of the mine workings. The description of the rocks penetrated is very meager. Two facts, however, are worthy of special note—no coal was encountered at the horizon of the high bed at localities 291 and 307, and four thin beds were found at horizons where the air shaft at locality 308 indicates absence of coal.

The record of this drill hole is as follows:

Record of diamond-drill hole No. 6, at locality 309, on ridge east of Rail Canyon.

	Ft.	in.
Sand and boulders	8	
Sand and gravel	4	
Shale	38	
Sandstone	14	
Shale	5	

	Ft.	in.
Sandstone	5	
Shale	2	
Sandstone	18	
Shale	6	
Sandstone	15	
Shale	9	
Sandstone	6	
Shale	11	
Sandstone	4	
Shale	5	
Sandstone	4	
Shale	3	
Coal		6
Sandstone	16	6
Shale	6	
Sandstone	7	
Shale	13	
Sandstone	8	
Shale	10	
Sandstone	2	
Shale	1	
Coal	1	
Sandstone	4	
Shale	9	
Sandstone	4	
Shale	6	
Sandstone	1	
Shale	5	
Sandstone	3	
Shale	5	
Sandstone	12	
Shale	15	
Sandstone	4	
Shale	6	
Sandstone	12	
Shale	8	
Sandstone	27	
Shale	24	
Sandstone	1	
Shale	12	
Sandstone	40	
Shale	11	
Sandstone	30	
Shale	17	
Coal	1	
Shale	9	
Coal	6	
Shale	17	
Bone		6
Coal	4	6
Bone	1	
Coal	2	6
Shale	1	

Another diamond-drill prospect nearly 3 miles farther south was put down on the ridge east of Spring Canyon, at locality 310, to test the character of the coal beds east of the mine workings. The number of coal beds in the lower part of the column (see Pl. XIV) indicates that the Vermejo formation may be thicker here than at neighboring localities.

The record of this drill hole is as follows:

Record of diamond-drill hole No. 5, at locality 310, in Spring Canyon, at the southeast corner of sec. 6, T. 28 N., R. 21 E.

	Ft.	in.
Sandstone	47	
Shale	3	
Sandstone	5	
Shale	2	
Sandstone	9	
Shale	4	
Shale, gray	6	
Coal	1	
Shale, gray	4	
Shale	20	
Shale, gray	1	
Shale, black	8	
Shale	20	
Shale, gray	10	
Shale, dark	5	
Shale, gray	18	
Shale, dark	7	
Shale, gray	25	
Shale, dark	15	
Shale	18	
Shale, dark	15	
Shale	14	
Shale, dark	6	
Shale	5	
Shale, dark	2	
Shale, gray	5	
Shale, dark	5	
Bone	8	
Shale, dark	10	
Bone	2	
Shale	5	
Shale, dark	7	
Bone	1	
Shale, dark	1	
Rock, hard	9	
Shale, dark	13	
Shale, gray	6	
Sandstone	4	
Shale, dark	2	
Shale, gray	2	
Bone	1	
Shale, dark	2	

	Ft.	in.
Shale, gray	1	
Coal		6
Shale	1	
Coal		6
Bone		6
Coal		9
Shale, dark	3	6
Sandstone, coarse	7	
Sandstone	2	
Shale, dark	1	
Coal		4
Shale, dark	3	8
Shale	5	
Coal		8
Shale, dark	3	2
Sandstone	4	
Shale, dark	2	
Bone	1	
Shale, dark	15	
Coal	1	8
Sandstone	3	4
Shale, dark	3	
Shale	2	
Bone		6
Shale, dark	6	
Bone		6
Coal	5	
Shale	1	
Shale, dark	1	
Coal		6
Sandstone	8	6
Shale	2	
Coal	1	
Bone	1	
Shale, dark	2	
Sandstone, coarse	3	
Sandstone	66	
Shale	8	
Sandstone	4	
Shale	4	
Sandstone	1	

Still farther south, in the spur between Vermejo Canyon and Spring Canyon, at locality 311, a section of the Vermejo formation and neighboring beds was measured at the surface. Here the Trinidad sandstone is conspicuously exposed and the basal sandstone of the Raton formation resists weathering more than the rocks above and below it; hence it forms a bench. At the spot where the measurements were made the upper part of the highest coal bed has been eroded and the basal sandstone of the Raton formation lies unconformably on the coal.

The section at this locality follows:

Section of rocks at locality 311, about 2 miles east of Dawson.

	Ft.	in.
Raton formation:		
Sandstone, massive; friable at base; coarse grained and quartzose near top	20	
Unconformity.		
Vermejo formation:		
Coal		9
Shale, drab to yellow, with partings of shaly, yellow sandstone	57	
Coal	1	6
Shale, drab	7	
Coal		10
Shale, black	1	
Sandstone, white, granular, friable	11	
Coal	2	6
Shale	3	
Coal	1	
Shale, drab to black	3	
	88	7
Trinidad sandstone	110	
Pierre shale:		
Transitional zone.		
Shale.		
	218	7

About 2½ miles east of the last locality described the coal-bearing rocks cap Saltpeter Mountain, an outlier of the highlands to the west, from which it is separated by erosion. On the west slope of this outlier, at locality 312, the following section was measured:

Section of rocks at locality 312, on west slope of Saltpeter Mountain.

	Ft.	in.
Raton formation:		
Sandstone, coarse grained, cross-bedded	20+	
Unconformity.		
Vermejo formation:		
Coal	4	6
Shale	5	
Sandstone, coarse grained, white (Rail Canyon sandstone)	8	
Coal		6
Shale		8
Coal		4
Shale	10	
Coal, shaly		8
Shale	5	
	34	8
Trinidad sandstone	100	
Pierre shale:		
Transitional zone and shale, fossiliferous	400+	
	554+	

On the east slope of Saltpeter Mountain, at locality 313, and at the southern end, at locality 314, sections of the coal-bearing rocks were measured for comparison with section 312. These sections are as follows:

Section of rocks at locality 313, on east slope of Saltpeter Mountain.

	Feet.
Raton formation:	
Sandstone and shale.	
Sandstone, coarse-grained, conglomeratic	20
Vermejo formation:	
Coal	5
Shale	10
Sandstone (Rail Canyon)	8
Shale, yellow to dark, with thin beds of coal less than 6 inches in thickness	28
Trinidad sandstone.	
	71

Section of rocks at locality 314, on Saltpeter Mountain.

	Ft.	in.
Raton formation:		
Sandstone and shale.		
Sandstone, conglomeratic, base irregular	20±	
Vermejo formation:		
Coal	4	6
Shale	5	
Sandstone, coarse-grained (Rail Canyon)	8	
Coal		6
Shale		8
Coal		4
Shale	10	
Coal, shaly		8
Shale	5	
Trinidad sandstone.		
	34	6

The area north of Saltpeter Mountain is described under the Koehler district.

PRINCIPAL COAL BED IN THE DAWSON MINES.

The coal bed in which the Dawson mines are located is the main coal bed of the Vermejo formation, but there are some doubts as to its exact correlation with the bed known as the Raton coal bed, which is worked in the mines of the other districts. In the same sense that the coal at Van Houten is called the Willow coal and that mined at Koehler is locally known as the Koehler coal, that at Dawson is locally called the Dawson coal. It corresponds in position with the Koehler coal bed to the northeast in that it is near the base of the coal-bearing rocks, but whether it is continuous with the Koehler bed or thins out to the north as it does to the east has not been determined. As previously described, the Dawson coal bed is only a few inches thick in Saltpeter Mountain, where the bed

above the Rail Canyon sandstone thickens so much that it becomes the commercially important bed. As the Rail Canyon sandstone thins out in Five Dollar Canyon it is impossible to state whether the Dawson coal or the higher one represents the main coal bed of the Koehler district.

The details of the coal bed are here given in order from the south along the outcrop westward, northward, and eastward. The same order is followed in Pl. XV, in which the sections of the coal bed have been platted in order from left to right. The localities where the sections were measured are designated by numerals on the sketch map, Plate XIII.

The outcrop has been surveyed for a distance of several miles south of Lacy Canyon, and the coal was opened in several places years ago. The old prospect holes are not now accessible, however, and no records of them have been preserved.

An old report by Orestes St. John to the Raton Coal & Coke Co. indicates that an old mine in the south fork of Lacy Canyon was opened in a coal bed 6 feet 1 inch thick. This bed has recently been opened between the two forks of Lacy Canyon, where the following measurement was made in a prospect entry.

Section of coal bed at locality 292, in Lacy Canyon.

	Ft.	in.
Sandstone.		
Coal	1	4
Bone		3
Coal		7
Bone		1½
Coal		9
Bone		1½
Coal		6
Bone		8
Coal	1	6
	5	10

St. John's report indicates that this bed is 3 feet 1 inch thick in the north fork of Lacy Canyon. The coal extends through the spur to Dawson Canyon, where mines have been opened in it.

Mine No. 10, in the south wall of Dawson Canyon, was not accessible at the time of the writer's examination of the Dawson district, but the coal bed is reported to have essentially the same thickness and character as that described below for mine No. 9.

At the time of the writer's visit in 1919 mine No. 9 was being developed. The main entry had been driven in on the coal bed about 1,000 feet. At the end of this entry the following section was measured and a sample of the coal collected for analysis. At this locality the main coal is overlain by 8 feet of shale and 1 foot 6

inches of coal, and no sandstone is in sight. The Rail Canyon sandstone, which lies on the coal at locality 292, here lies at some undetermined distance above the main coal bed.

Section of coal bed at locality 293, in mine No. 9.

	Ft.	in.
Shale.		
Coal, bony	1	6
Shale		8
Coal (sampled; analysis 33019)		6
Coal (not sampled; left as floor)	3	
Shale.		
	15	9

Eight sections (295 to 302), which were measured in mine No. 7 to show the variable character of the coal, have been platted in Plate XV. From these sections it appears that the lower part of the coal is relatively free from impurity but that the upper part is very bony. It also appears that the Rail Canyon sandstone rests on the coal in some places and in others is 5 feet or more above the coal bed.

The coal is worked in the southern part of mine No. 7, but in the northern part work has been suspended because of the large amount of bone. The poor quality of the coal continues for a considerable distance north of this mine. The bed is thin at locality 303, and in the old mine No. 6, just north of locality 304, the coal was so bony that the mine was abandoned.

At locality 303 the upper bench of coal and the shale that overlies it at locality 302, near the opening of mine No. 7, apparently were eroded, and the Rail Canyon sandstone is low in the section, but at locality 304, less than half a mile to the north, both benches of coal are present. This sandstone can not be recognized in the record of the drill hole at locality 305.

Mine No. 5 is the westernmost of the group of well-developed mines near Dawson. It opens in Vermejo Canyon, about 1½ miles northwest of the town. These mines were once more or less connected, but after an explosion several years ago, which did much damage, the connecting openings were walled up for protection, so that now the mines are disconnected.

The coal bed in mine No. 5 is so regular in character that a few sections adequately represent it. Four sections, 315 to 318, have been platted on Plate XV, and their location in the mine is shown by the same numerals on the map. At locality 315 the coal is bony, and mining operations were not extended far west of this locality because of the poor quality of the coal. Elsewhere in this mine, however, the coal is fairly free from impurities. Its character is shown by analysis 33021 (p. 243), which was made on a sample collected at locality 316, where 5 feet 4 inches of coal occurs with shale above and below it.

The Rail Canyon sandstone rests directly on the coal in many places in mine No. 5, but in other places shale intervenes between it and the coal. In mine No. 2, which lies east of mine No. 5, the coal bed has essentially the same character and thickness as in mine No. 5 and the Rail Canyon sandstone forms the roof. The same is true of mine No. 3. However, near the north end of mine No. 3 a wedge-shaped parting begins as bone and thickens northward, changing to shale and finally to fine-grained flinty sandstone. Ten sections were measured at the north end of the mine to show this feature. They are too close together to be separately numbered, and have been collectively grouped as section 319. At the end of the main entry the parting is so hard that no attempt is made to remove it, and the lower bench of coal, 2 feet 11 inches thick, is temporarily abandoned. This parting is recognized in the drill record at locality 309, where it is called bone.

Mine No. 6 is little more than an entry leading back to a newly developed area northeast of the older workings. Three sections of coal bed were measured in this mine, at localities 320, 321, and 322. At locality 320 the Rail Canyon sandstone rests on bony coal, which seems to represent only the lower bench of the other sections. At locality 321 the total thickness of the bed is not known, but at locality 322 an upper bench of coal is 2 feet 6 inches thick and overlain by 1 foot of shale, which lies under the Rail Canyon sandstone. At this locality the lower bench, 6 feet 4 inches thick, was sampled for analysis. The results are given in analysis 33022 on page 243. The section measured here is as follows:

Section of coal bed at locality 322, in mine No. 6.

	Ft.	in.
Sandstone:		
Shale	1	
Coal	2	6
Bone		¼
Coal (analysis 33022)	6	4
Bone		3
Shale.		
	10	1¼

Farther south, in mine No. 4, the coal bed is relatively thin and the coal is bony. The character of the bed is indicated by sections 323 to 326. Prospects south and east of this mine show the variations in thickness and in the character of the coal bed. On the spur at locality 311 the bed is thick but contains much shale and bone. Farther east, in Spring Canyon, at locality 327, the coal occurs in three benches. It probably thickens northward to 5 feet at locality 310, where it was penetrated by the drill, although there is a reasonable doubt of this correlation, as the thickest bed of coal shown in the drill records may not be the Dawson coal. The lowest or 2-foot

bed of coal penetrated by the drill is in the position of the Dawson coal, but the thicker bed may prove to be the one above the Rail Canyon sandstone. The thickness increases eastward to 5 feet 1 inch, with one bony parting, at locality 328, and 5 feet 10 inches, with a thicker parting, at locality 329. The bed becomes thinner southward and contains 3 feet of shaly coal at the southern end of the long spur east of Spring Canyon and is represented in Saltpeter Mountain by only a few inches of coal.

The bed also becomes thinner northward from locality 329 and contains much bone, as indicated by sections 330, 331, and 332. At the point where the outcrop of the coal crosses Saltpeter Canyon a thickness of 1 foot 11 inches is reported in one old prospect and 3 feet 1 inch in another. A more recent prospect opening near the same place, the exact location of which can not now be given, shows the following section:

Section of coal bed in Saltpeter Canyon.

	Ft.	in.
Shale.		
Coal	1	8
Shale	2	6
Coal		6
Shale	4	
Coal		6
Shale.		
	9	2

Little has been done in opening the coal in the east wall of Saltpeter Canyon. A thickness of 3 feet is reported at the southern end of the spur and of 4 feet 6 inches about a mile farther north.

The Rail Canyon sandstone has not been recognized in all places, and little is known of the coal beds above it. In Dawson Canyon, at locality 294, two thin beds of coal occur above this sandstone. Sections 303, 304, and 305 were measured before this sandstone was known to have special significance, and its place in the sections has not been determined. In the air shaft at locality 306, however, the Rail Canyon sandstone was examined, and the coal bed above it was measured and sampled as follows:

Section of upper coal bed at locality 306, in mine No. 5.

	Ft.	in.
Sandstone.		
Shale		6
Coal		3
Shale		3
Coal (analysis 33020, p. 243)	2	9
Shale.		
	3	9

Probably one of the coal beds in the sections measured farther east corresponds to this upper coal, but this can not be confidently asserted.

However, on Saltpeter Mountain, the Rail Canyon sandstone was recognized by its peculiar characteristics, and the coal above it, here the thickest bed of the section, holds the same stratigraphic position as the upper coal at locality 306.

MINES IN THE DAWSON DISTRICT.

The several mines at Dawson are so closely grouped that they virtually form one mine. Throughout the developed area the Rail Canyon sandstone lies either directly on the coal or so close that it virtually constitutes the mine roof. This sandstone makes a strong roof, and serious falls of roof material are rare. In places where shale intervenes between the sandstone and the underlying coal a few slips, horsebacks, and rolls have developed. In many places the upper part of the coal is so bony that it is left as roof.

The mines yield a relatively hard coking bituminous coal of the quality shown by analyses given on page 243. It is only slightly affected by the weather, and where exposed for years at the outcrop it has not crumbled. It is only slightly affected by faults and folds. The cleat faces are moderately well developed, and in general the rooms are driven on the faces and entries on the butts.

The floor of the mines consists of firm shale in some places and coal in others. There is little tendency of the shale to creep or heave.

Drift entries to the mines are driven in on the coal bed, and the workings are laid out on the room and pillar plan. Top coal is left in some places for removal on retreat, when the pillars also are removed.

Electrically driven exhaust fans, reversible if reverse is needed, furnish means of ventilation, and pumps furnish the slight amount of drainage needed.

In mining the coal is undercut by machine and shot down with "permissible" powder. All shooting is done electrically by shotfirers, after all men are out of the mine. The loaded coal cars are hauled in the mines by mules to central points from which they are hauled by electric motor to the tipples.

The coal is used to some extent for domestic fuel and for making steam, but a large part of it is coked. When the writer visited Dawson there were 570 coke ovens of 6 tons capacity running at full capacity and coking an average of 1,020 tons a day. The ovens were of two kinds: 446 were underflue ovens and 124 were of the beehive type. The waste products are utilized to some extent. The gas furnished 4,000 horsepower, and 2,000 more was available. All power used in the mines and in the town is produced by this gas.

The coal is crushed and washed in a manner similar to that employed in the concentration of metalliferous ore. The tables were patterned

after those used in copper concentration. About 15 per cent of the material by weight is removed. The coal that is thus freed in large measure from bone is coked for use in the smelters of the Southwest.

The mines are equipped with modern machinery. At the time of investigation there were 2,100 steel cars of 3,500 pounds capacity. The tracks were of 36-inch gage. The main entry tracks have 45-pound rails and the rooms 16-pound. The tipples are of steel and wood, with rotary dump, kick-back, feeder screens, picking booms, and box-car loaders. The screens are perforated, sizing the coal as follows: Special pea, three-fourths inch to 1½ inches in diameter; fancy nut, 2 to 3 inches in diameter; fancy egg, 3 to 4 inches in diameter; lump, 4 inches or more. The coal is all picked on the belt, but not all of it is screened.

COAL BEDS IN THE RATON FORMATION.

GENERAL FEATURES.

There are two well-defined groups of coal beds in the Raton coal field in the younger of the two coal-bearing formations. A lower group of minor importance near the base of the formation is known as the "Sugarite zone," a name derived from the Sugarite mine operating on the thickest bed of the group. This group is overlain by cliff-making sandstones, locally known as the "barren series," because it contains no minable coal. Above the "barren series" is the upper group of coals, which contains many beds of coal, several of which are thick enough to be of economic importance under present mining conditions.

The rocks in which this upper group of coals occurs are approximately 500 feet thick in the eastern part of the field, but thicken to double that amount in the western part of the Brilliant quadrangle. This eastward thinning is due largely to the removal by erosion of the younger beds prior to the deposition of the unconsolidated sand and gravel that intervenes in the eastern part of the field between the coal-bearing rocks and the sheets of lava which cap the mesas, but it is due to some extent also to differences in original deposition. The sediments of the Raton formation were derived from the west and seem to decrease in thickness and to become finer eastward. The occurrence and horizon of the coal beds, their thickness, and their relation to each other where the relations are known are best indicated in Plate XVI, in which have been platted to the same scale the best drill records obtainable, together with some of the sections measured at the outcrop. The drill records and sections have been arranged with the top of the Trinidad sandstone as a datum plane. As the coal beds are of prime importance for the purposes of this bulletin, the sandstone and shale of the intervening beds have not been platted.

COLUMNAR SECTIONS AND DRILL RECORDS.

Drill records AA and BB of Willow Canyon include only rocks below the upper coal group but are here included because they help to interpret the records that follow. A hole put down at locality CC on the south fork of Coal Creek, a tributary of Canadian River in the south-central part of the Brilliant quadrangle, about 1⅘ miles northwest of locality BB, penetrated the lower part of the coal-bearing rocks of the upper coal group and was extended through the two underlying groups of coal beds into the Trinidad sandstone. Unlike the records in the eastern part of the field near Yankee, this record shows only thin beds of coal near the base of the upper group. The lowest coal of this group having any considerable value is the 4-foot bed, which is a little more than 100 feet beneath the surface and which seems to correspond to the Tinpan coal bed of the Brilliant region. (See section FF, Pl. XVI.) The second hole in Coal Canyon, at locality DD, also penetrated to the Trinidad sandstone, but it was started below the horizon of the upper coal group.

The drill hole in Potato Canyon, at locality EE, is 3.9 miles northwest of the last hole described and penetrated near the surface one thick bed of coal and three thin beds. The hole was sunk well into a sandstone that was supposed to be the Trinidad. If this lowest sandstone is the Trinidad it is difficult to harmonize the record with the data obtained at neighboring localities.

The 4-foot coal of drill record CC was identified at the surface in Coal Canyon and in McClellan Canyon and almost continuously, as shown below (pp. 168 et seq.), from Potato Canyon northeastward to Brilliant, where it is known as the Tinpan coal and where the drill hole put down in Tinpan Canyon at locality FF indicates that it occurs at the same horizon as the 4-foot bed of the Coal Canyon record. In Potato Canyon the Tinpan coal lies approximately 115 feet below a thick bed called the Potato Canyon coal, which has been traced at the outcrop and opened in several places in Potato, Canadian River, Jones and Rombo canyons. A bed interpreted locally as the Potato Canyon coal was penetrated by the drill about 60 feet below the surface at locality EE in upper Potato Canyon. It was the belief of the engineers that the entire thickness of the coal-bearing rocks was penetrated and that the drill entered the Trinidad sandstone. However, comparison with other records seems to render another interpretation more plausible. The occurrence of two thick beds of coal at the outcrop in Potato Canyon, whereas the drill penetrated only one, suggests that this one is the lower or Tinpan coal, rather than the higher or Potato Canyon coal. In drill record CC the Tinpan bed is 677 feet above the base of the coal-bearing rocks. Although an unconformity occurs in the rocks penetrated the beds lie so nearly

horizontal that it probably does not affect the correlation of the coal beds. Near Brilliant, at locality FF, this coal is 674 feet above this base. The thick bed of coal penetrated by the drill at locality EE in Potato Canyon, is 678 feet above the bottom of the hole. If this coal represents the Tinpan bed the drill probably did not reach the base of the coal-bearing rocks and therefore did not prove the absence there of the Raton coal, as has been supposed. On the other hand, if the thick coal of this record is the Potato Canyon bed, as is locally believed, there is a thickness of about 115 feet of coal-bearing rocks between the bottom of the hole and the base of the coal-bearing rocks. On the whole it seems probable that the thick bed of coal at locality EE in Potato Canyon may be the Tinpan bed, and the record in Plate XVI has been platted in accordance with this assumption. This is opposed by the engineer's mapping, which has been used on the map (Pl. I.)

Several drill holes that have been put down in the vicinity of Brilliant give much more accurate information as to the number of the coal beds in that district than can be obtained from surface indications. The Brilliant district is closely connected, by means of the line of drill holes previously described from Dillon Canyon, with the developed area near Blossburg, where the Raton coal has been extensively worked. The drill holes at localities Q to T, inclusive (see Pl. XVI), in Dillon Canyon were all started below the horizon of the Tinpan bed, but the hole at locality FF in Tinpan Canyon, about 1¼ miles west of locality T, was started above this bed. Several thin beds of coal in the lower part of the upper coal group below the Tinpan bed were penetrated. Two thin beds were found in the "Sugarite zone" and a bed of coke at the horizon of the Raton coal. The drill was stopped in Trinidad sandstone.

This locality is nearly 9 miles from the drill hole at locality EE in Potato Canyon, a distance that might render doubtful any exact correlation of the beds penetrated unless confirmatory data were obtained at intermediate localities. The Tinpan bed lies 674 feet above the Trinidad sandstone, a horizon corresponding closely to that of the thick bed in Coal Canyon at locality CC. The Tinpan bed has been traced at the outcrop southward most of the way to Potato Canyon as shown in Plate I, though there is some uncertainty in places, and it has been opened at short intervals, so that there is good reason to believe that it extends continuously southward to Potato and Coal canyons and that it is identical with the thick bed penetrated by the drill near the surface in these two canyons, as indicated by the correlation lines on Plate XVI.

The second hole was put down west of Brilliant, at locality GG, in Tinpan Canyon, 2,800 feet northwest of the first. Two thin beds

were found above the Tinpan coal and four thin beds in the lower part of the upper coal group. One bed, consisting of three benches of coal, was penetrated in the "Sugarite zone," and the drill stopped in igneous rock, which is probably the same as that penetrated in Tinpan Canyon at locality FF. Four other holes (HH, II, JJ, and KK) were put down near Brilliant with the results shown in Plate F. These records have been correlated by means of the Tinpan bed, which was identified in each hole by its character and altitude.

The records of the holes at locality II and JJ show the occurrence of numerous beds of coal above the Tinpan bed, but most of them are thin and of doubtful value, and it is impossible at present to correlate them with beds at neighboring localities. The number and position of the beds in each hole indicates that some of the coals are not continuous for any considerable distance, and this fact raises doubt as to the real continuity for any considerable distance of any of them. For example, in Potato Canyon the thick bed of coal about 115 feet above the Tinpan bed is known as the Potato Canyon coal. The bed 120 feet above the Tinpan coal in Dillon Canyon, at locality KK, has been supposed to be the Potato Canyon bed, but no bed of corresponding thickness was found in the neighboring drill holes at this horizon, and at locality II a thick bed, which some call the Potato Canyon coal, is about 275 feet above the Tinpan coal.

In McBride Canyon, north of the Brilliant quadrangle, a thick bed of coal, which some have regarded as the Potato Canyon bed, crops out at Wootton, Colo., and has been penetrated by the drill east of that town. (See Pl. XVI.) The record of the first hole is supplemented by that of a second hole started at a horizon below the Wootton bed and put down to a horizon considerably lower than that reached in the first, as shown in the sections in Plate XVI. If the Wootton coal is equivalent to the Potato Canyon coal the Tinpan bed should have been found about 115 feet below it, but no such bed was penetrated by the drill. On the other hand, if the Wootton coal is equivalent to the highest thick bed in Coal and Tinpan canyons a bed representing the Tinpan coal should occur about 250 feet below it. It is possible that the bed 2 feet 2 inches thick penetrated by the drill about 220 feet below the Wootton coal represents this bed.

Still greater uncertainty exists regarding the identity of the beds found farther east. Very little is known of the coal beds of the upper group in Bartlett Mesa, in the Raton quadrangle. No drill holes have been put down in this mesa and few prospect openings have been made. The want of information regarding the upper group of coal beds between Brilliant and Yankee is supplied to some extent by sections measured at the outcrop. Some of the more complete sections have been platted together with the drill records in Plate XVI.

A section was measured with a Locke level in the side of Bartlett Mesa, north of Raton, from locality 261 to the top of the mesa. (See Pl. XVI.) The top of the Pierre shale is exposed in the bottom of the canyon, and the Trinidad sandstone is typically developed here. The thickness of the Vermejo is reduced to 33 feet, and the formation here contains only one bed of coal instead of the three beds found in some places farther west. The basal sandstone of the Raton formation is here only 4 feet thick but hard and quartzose, and a few small pebbles of quartz and chert were found in it. It rests with uneven base on softer rocks.

Above this basal sandstone the rocks consist principally of shale for about 125 feet, and in this shale occurs the Sugarite coal, the lowest bed of commercial value in the Raton formation and the thickest bed of the "Sugarite zone." Above the massive cliff-making sandstone of the "barren series" is the zone of coal-bearing rocks of the upper coal group. The higher beds of this group were eroded before the lava which forms the cap of Bartlett Mesa was poured out upon the surface.

The columnar section measured north of Raton at locality 261 is as follows:

Section of rocks at locality 261, on slope of Bartlett Mesa.

[For graphic section see Pl. XVI.]

	Ft.	in.	Ft.
Basalt, underlain in some places by unconsolidated sand and gravel	100		
			100
Raton formation:			
Covered	50		
Shale and sandstone in alternating layers	50		
			100
Coal	1		
Shale	4		
Sandstone, massive, cliff-making	35		
Shale	30		
			69
Coal		6	
Shale	30		
Coal	2	4	
Shale	4		
Sandstone, cliff-making	30		
Shale	90		
Sandstone, cliff-making	30		
Shale	10		
			164
Coal	4	10	

Raton formation—Continued.	Ft.	in.	Ft.
Shale	29		
Shale	10		
Shale, carbonaceous, with thin beds of coal	3		
Sandstone and shale	20		
			62
Coal	1		
Sandstone and shale in alternating layers	60		
Coal	1	8	
Shale	1	4	
Coal	1		
Shale	1		
Coal with shale partings	1	4	
Shale	35		
Sandstone, massive, cliff-making	30		
Shale, carbonaceous	20		
			85
Coal	1	4	
Shale		6	
Coal	1	6	
Shale	1		
Coal with shale partings	2		
Shale	35		
Sandstone, cliff-making	30		
Sandstone and shale in alternating layers	60		
Shale, carbonaceous, with thin beds of coal	2		
Shale	29		
			156
Coal	1	8	
Shale	20		
Sandstone, cliff-making	20		
Shale	25		
Sandstone	12		
Sandstone and shale in alternating layers	45		
Sandstone, massive, cliff-making	75		
Shale and sandstone in alternating layers	40		
Sandstone	20		
Shale	20		
			277
Coal	1		
Shale, carbonaceous	20		
Coal (Sugarite bed)	1	8	
Shale	15		
Coal		10	
Shale	29		
Shale, black, carbonaceous, with thin beds of coal near the base	5		
Shale	10		
Sandstone	10		
Shale, carbonaceous near the base	21		
Sandstone, locally conglomeratic	4		

	Ft.	in.	Ft.
Unconformity.			
Vermejo formation:			
Shale and sandstone	15		
			94
Coal		5	
Shale	1	10	
Coal	4	7	
Shale	11		
Trinidad sandstone	100±		
Pierre shale.			
	1,386±		

Another section was measured about 1½ miles farther east, in the east wall of Linwood Canyon at locality 242. The rocks in this canyon are not well exposed in some places, but some significant features are well developed. The Pierre shale and the Trinidad sandstone have the same appearance that they have farther west but the Vermejo formation is not present. The conglomeratic sandstone at the base of the Raton formation, which is only 4 feet thick at locality 261, where the section just described was measured, is here 25 feet thick and rests on the Trinidad sandstone. The "Sugarite zone" and the "barren series" are well developed. Several coal beds were found in the upper coal zone, but owing to poor exposures their relation to beds in neighboring sections could not be accurately determined. The section as measured here has been platted on Plate XVI.

On the southeastern point of Bartlett Mesa, near locality 435, the section described below was measured with a Locke level and platted in Plate XVI as the Linwood section. The Pierre shale is here exposed in barren slopes at the foot of the mesa and contains concretions of limestone. The Trinidad sandstone does not differ in any notable way from the Trinidad at neighboring localities, except that the upper few feet of it is different in appearance from the material at the top of this sandstone where the Vermejo beds are present. The upper part here is rusty brown and is harder than the underlying sandstone, so that it stands out as a shelf in the side of the mesa. Its upper surface is irregular, which suggests that it once formed a surface of erosion.

The basal sandstone of the Raton formation, which is 25 feet thick at the last locality described, becomes thinner toward the east and was not found in the southeastern point of Bartlett Mesa, although it was observed in many places farther east. The shale of the Sugarite zone here seems to rest directly on the Trinidad sandstone. The cliff-making sandstones above the "Sugarite zone" are prominent, and above them occur the several coal beds of the lower part of the upper coal group. The higher beds of this group were

eroded before the lava of the mesa was poured out on the surface. Because of the westward inclination of the sedimentary rocks the beds occur progressively higher toward the east, but the igneous rock of the mesa cap slopes in the opposite directions and lies across the eroded edges of the sedimentary beds. For these reasons the igneous rock at the top of this section, although the same as that of the two sections previously described, appears to be much lower in the section. (See Pl. XVI.)

In the opposite wall of Sugarite Canyon, just east of the boundary of the Maxwell Land Grant, a columnar section was measured with a Locke level at the south end of Horse Mesa. The rocks between the Pierre shale and the lowest coal bed of the upper coal group, here known as the Yankee coal, are well exposed, but the higher beds are obscured by brush and slide rock. The section has been platted in Plate XVI.

On the east slope of Horse Mesa several drill holes were put down by the Yankee Fuel Co., but at the request of the company the exact location of these drill holes is not indicated. One hole was started near the top of the mesa and extended through the coal-bearing rocks. Near the bottom of the hole a sandstone was penetrated which is doubtless the Trinidad. This hole probably gives the best record of the succession of beds in Horse Mesa, and it is therefore given in detail below:

Section of rocks penetrated by diamond drill in Horse Mesa.

[For graphic section see Pl. XVI, p. 152.]

	Ft.	in.
Shale, sandy	49	
Sandstone	4	6
Coal, shaly		6
Shale	1	2
Coal	1	8
Shale		2
Coal	1	
Shale	33	
Coal	2	1
Coal, shaly		11
Coal	2	8
Shale, sandy	6	8
Coal	1	1
Shale	13	
Coal	1	6
Shale	41	
Sandstone	29	8
Coal, shaly		4
Shale	3	4
Coal		8
Shale		5
Shale, with thin seams of coal	1	4

	Ft.	in.
Shale	5	3
Coal		3
Shale, sandy	35	4
Coal		9
Shale	13	8
Coal		7
Shale	16	5
Shale, with thin seams of coal	1	
Coal	1	7
Shale	5	5
Coal, shaly	1	10
Shale	27	2
Coal		7
Shale	85	3
Coal	1	10
Shale, sandy	39	9
Coal	1	10
Shale, sandy	4	1
Coal		4
Shale	4	10
Coal		10
Coal, shaly	1	3
Coal		5
Shale	1	
Coal	1	2
Shale, sandy	17	4
Coal		5
Sandstone, shaly	26	8
Coal		5
Shale, sandy	6	8
Coal	1	4
Shale	4	1
Coal	1	1
Shale		10
Coal	1	
Shale	8	4
Coal, shaly		6
Coal		8
Shale		6
Coal		4
Shale		8
Coal	1	4
Shale	12	6
Coal, shaly		7
Shale	1	4
Coal, shaly		8
Sandstone with layers of shale	205	8
Shale	11	8
Coal		11
Sandstone with layers of shale	40	3
Coal		3
Shale		4
Coal, bony		6

	Ft.	in.
Shale	1	1
Coal	2	9
Shale	1	7
Coal		6
Shale, sandy	28	1
Coal	3	
Shale with thin bands of sandstone	62	7
Sandstone (Trinidad)	8	6+
	903+	

A well bored in the western slope of Barilla Mesa east of Yankee gives a good section of the lower part of the coal-bearing rocks but was not started high enough to include the highest beds of coal. The record of this boring is as follows:

Section of rocks penetrated by diamond drill in western slope of Barilla Mesa, east of Yankee.

[For graphic section see Pl. XVI, p. 152.]

	Ft.	in.
Surface material	6	
Shale	2	
Coal	1	
Shale	3	
Coal		6
Shale	17	2
Coal		2
Shale	4	2
Sandstone	16	
Coal, shaly	3	6
Shale	1	2
Coal	2	
Shale, sandy	20	9
Coal	4	2
Sandstone	37	5
Shale	10	
Coal		6
Shale	1	10
Coal	1	6
Shale	5	2
Sandstone	18	
Coal	1	
Shale, sandy	32	6
Coal		6
Shale		10
Coal		4
Sandstone and shale	22	8
Coal		3
Shale, sandy	6	8
Coal		4
Shale, sandy	36	2
Coal		6

	Ft.	in.
Sandstone and shale	120	
Coal, shaly		4
Shale		2
Coal		8
Shale, sandy	10	
Coal		6
Sandstone and shale	9	2
Coal		4
Shale	17	
Coal		3
Shale	6	
Coal		4
Shale	15	
Coal		6
Shale, sandy	20	
	458	

In only a few places east of Barilla Mesa are the coal-bearing rocks well exposed. Fortunately, however, the lack of good exposures is supplied by the record of a drill hole which penetrates all the beds between the Trinidad sandstone and the basalt that caps Barilla Mesa. This record is as follows:

Section of rocks penetrated by diamond drill on east slope of Barilla Mesa.

[For graphic section see Pl. XVI.]

	Ft.	in.
Shale, sandy	71	
Shale, with thin seams of coal	9	7
Coal	2	1
Shale with thin beds of sandstone	50	11
Coal		10
Shale		2
Coal	2	1
Shale	2	8
Coal	2	8
Shale	11	
Coal, shaly	1	6
Shale, sandy	15	
Coal		6
Shale	6	8
Coal, shaly		6
Shale	6	4
Coal, shaly	3	
Shale		10
Coal		8
Shale and sandstone	32	8
Coal, shaly		6
Shale, sandy	15	10
Sandstone	31	

	Ft.	in.
Sandstone, with thin beds of coal	2	2
Coal	2	5
Shale		5
Coal	1	2
Shale, with thin beds of coal	1	4
Sandstone and shale	111	
Coal, shaly		4
Sandstone and shale	128	
Coal	3	2
Shale, sandy	39	11
Coal	1	
Shale	14	3
Coal	1	1
Shale, with sandy layers	45	9
Sandstone (Trinidad)	18+	
	638+	

The rocks are so poorly exposed in the sides of Johnson Mesa that at no place could a complete section be measured. However, a drill hole started on top of the mesa about 1 mile northeast of the Llewellyn mine (locality 576) was put down to a depth of about 475 feet. The drill penetrated 184 feet of basalt and then entered coal-bearing rocks. The highest coal bed seems to be the Llewellyn coal. Thin coal beds were found through a thickness of 108 feet below the Llewellyn bed, but the lower 116 feet of the record indicates absence of coal, and this part of the hole is evidently in the "barren series." The essential features of this record are shown in Plate XVI (p. 152).

The coal beds of the upper coal group vary in number from place to place and individual beds are so variable in character that a coal opened at a given locality must be carefully traced into a known area before its identity can be established. This fact is emphasized in the detailed descriptions which follow. The younger beds are much more irregular than the older ones. The beds of Cretaceous age in the Vermejo formation are relatively regular in thickness and character for long distances, except where they were removed by the post-Cretaceous erosion. The next younger coal—the Sugarite—although too thin in most places to be of much economic value, is continuous and relatively regular in thickness and character throughout the coal-bearing area of the Raton quadrangle and throughout a considerable part of the Brilliant quadrangle. Even the best known of the higher beds, however, can not be identified with certainty more than a few miles from their type locality.

The Tinpan coal mined at Brilliant can be identified with reasonable certainty as far south as Potato Canyon, a distance of 7 miles or more. The Potato Canyon coal, which in Potato Canyon lies 115 feet above the Tinpan bed, can not be traced with certainty much

beyond the confines of that canyon, and there is uncertainty of its identity near the head of that canyon. Farther north the Potato Canyon bed seems to have been confused by some with the underlying Tinpan bed on the one hand and with a higher bed of coal on the other hand. Near Raton Tunnel the Savage Canyon-Wootten coal has been supposed by some to be the Potato Canyon bed and by others to represent the thick coal above the Potato Canyon bed.

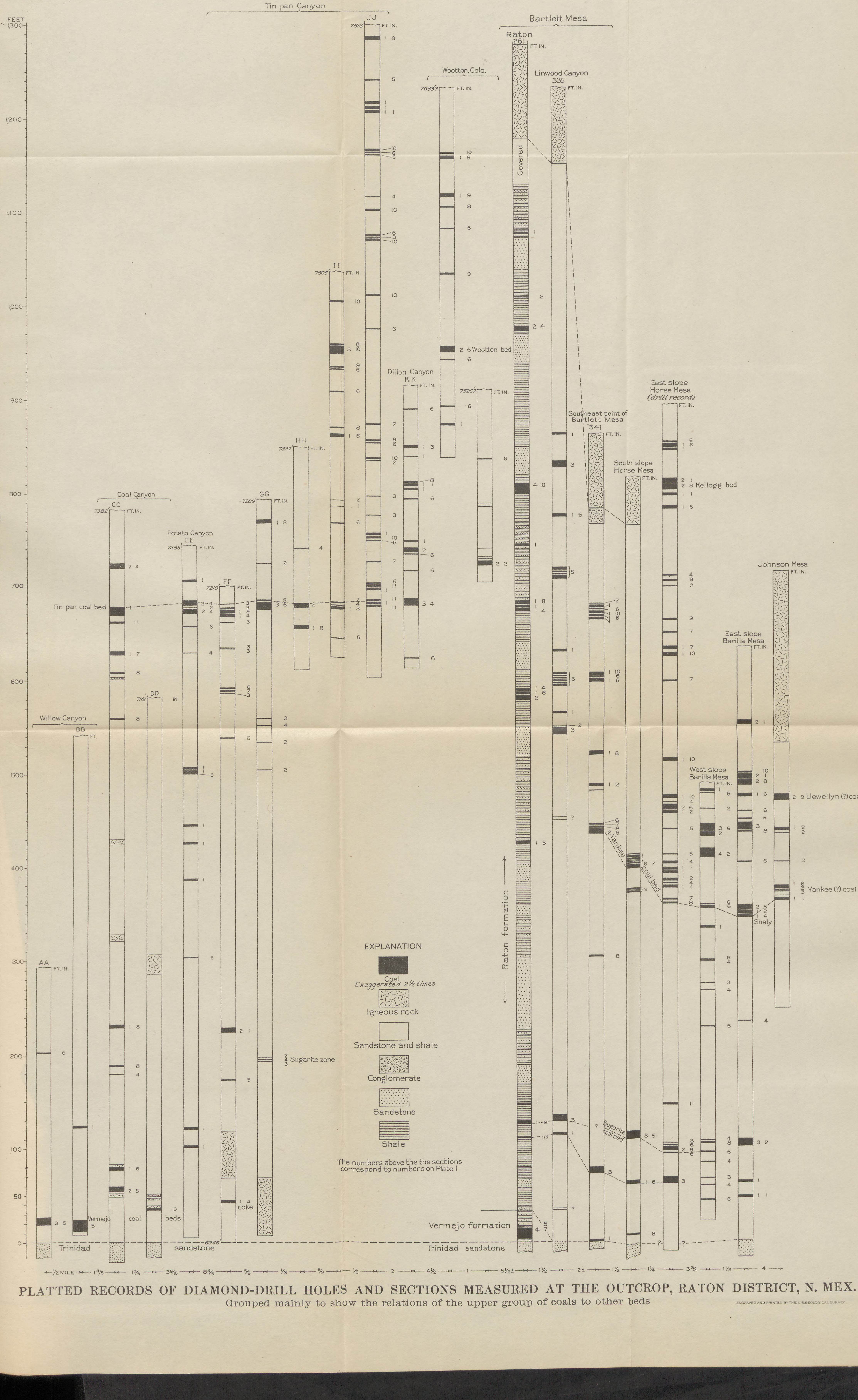
Near Yankee the lowest thick bed of the upper coal group, called the Yankee coal, is much lower in the section than the Tinpan bed, which is the lowest valuable coal in the upper group west of Raton. Other names given to coal beds in the Yankee district, such as Metcalf, Reynolds, and Llewellyn, are applied locally, and the beds have been traced only short distances from the mine giving the name. These facts will be emphasized in the detailed descriptions which follow.

COAL BEDS OF THE "SUGARITE ZONE."

GENERAL FEATURES.

The lowest commercially valuable coal bed in the Raton formation occurs in the "Sugarite zone" and is called the Sugarite bed from the mine of that name which has been opened at Sugarite in the Canyon of Chicorica Creek (see Pl. XVII, *B*), where the bed attains its maximum known thickness. It lies about 85 feet above the base of the formation in the vicinity of Yankee, where both horizons were penetrated by the drill. A coal bed at approximately the same distance above the base of the formation crops out in many places throughout the Raton and Brilliant quadrangles and was also penetrated by the drill in several prospect holes west and south of Blossburg, although the occurrence of more than one bed in this zone of coal-bearing rocks in some places renders the identity of the Sugarite coal doubtful. In some of these drill holes and in some of the sections measured at the outcrop thin beds of coal were found at several horizons in the "Sugarite zone." It is probable that these beds are more or less lenticular and that no one of them is persistent throughout the field. However, in many places the thickest coal in this zone occurs at so nearly the horizon of the coal mined at Sugarite that, for the present at least, it is assumed to represent the Sugarite bed.

Practically all the prospecting on these lower coal beds has been done east of Raton, and with few exceptions the openings are in the Sugarite bed proper. West and south of Raton all that is known of these coals has been learned from observations made at outcrops and from the records of drill holes put down through them during the explorations in search of the thicker coal beds lying both below and above the "Sugarite zone." At none of these localities was the Sugar-



PLATTED RECORDS OF DIAMOND-DRILL HOLES AND SECTIONS MEASURED AT THE OUTCROP, RATON DISTRICT, N. MEX.

Grouped mainly to show the relations of the upper group of coals to other beds

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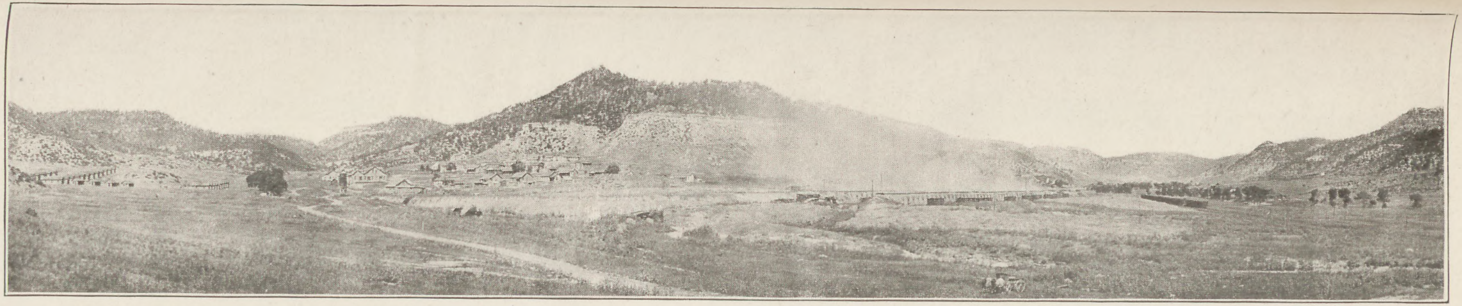
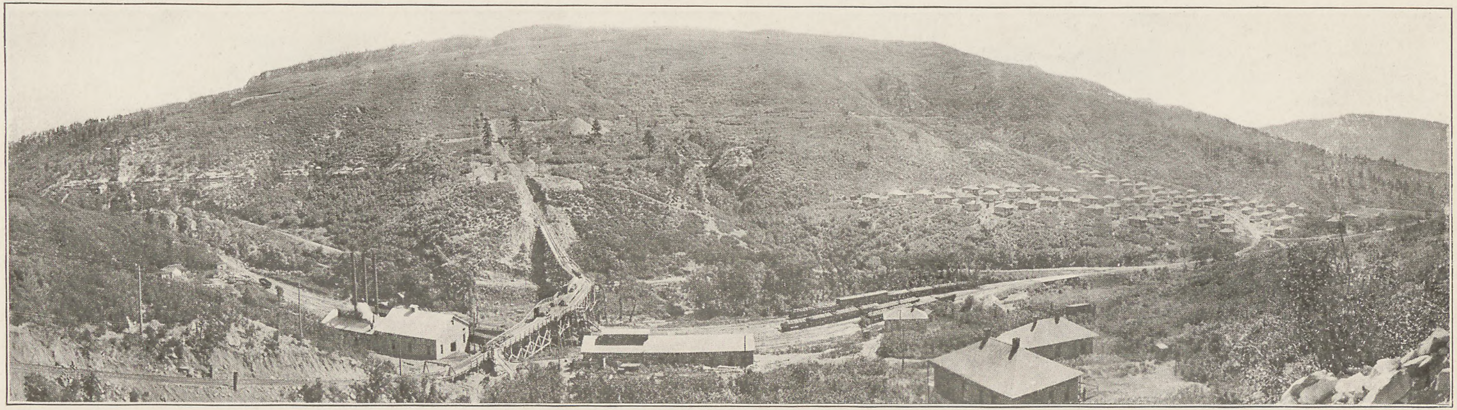


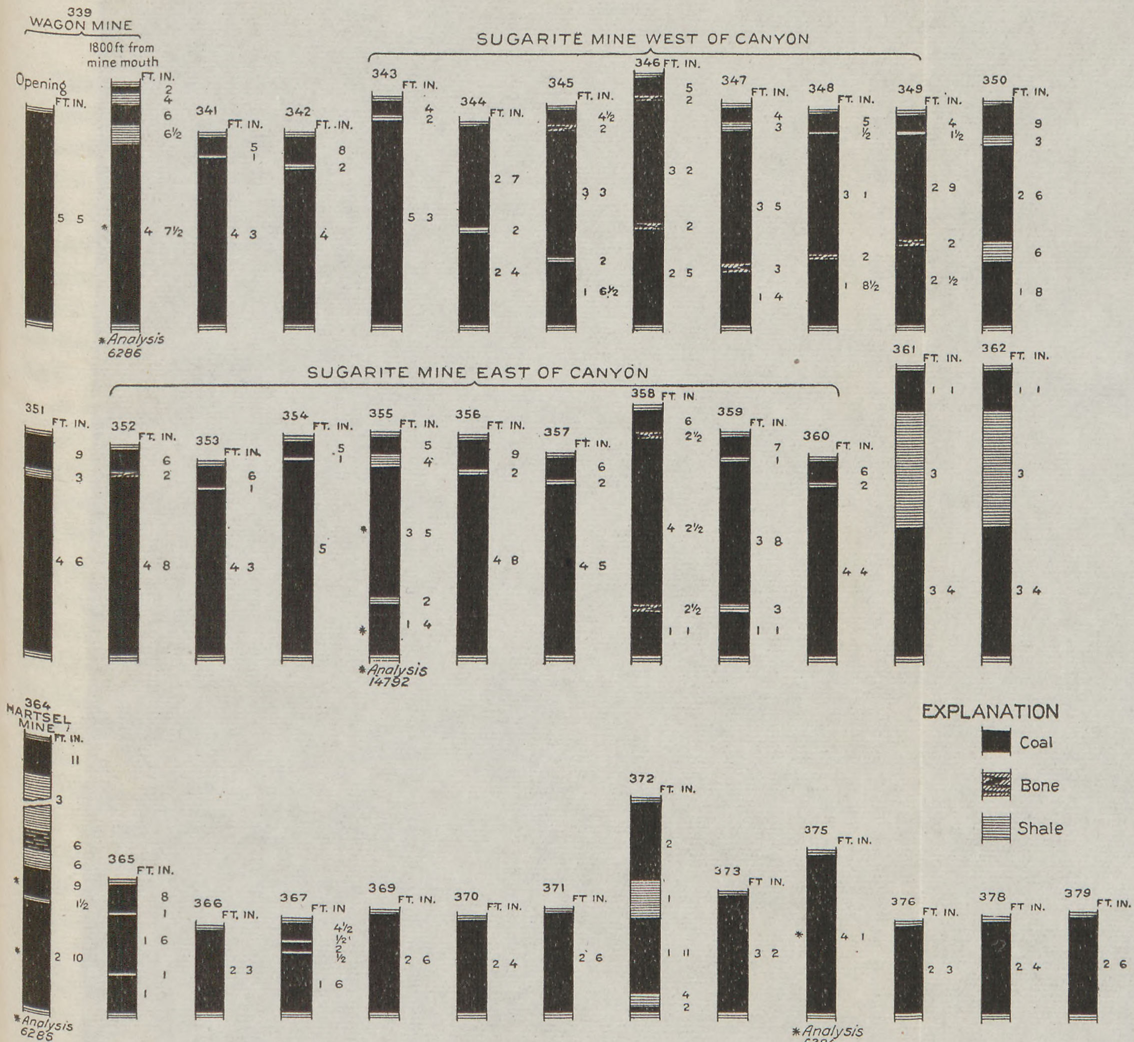
A. GARDINER CANYON (TO THE LEFT), DILLON CANYON (TO THE RIGHT), AND GARDINER COKE OVENS (BETWEEN).

The Pierre shale crops out in the foreground. The cliff back of the town is Trinidad sandstone. The Raton coal bed crops out just above this cliff.



B. SUGARITE (TO THE RIGHT) AND THE EASTERN OPENING OF THE MINE IN THE SLOPE OF HORSE MESA.

The Trinidad sandstone, which lies about 100 feet below the Sugarite coal bed, crops out on both sides of the tramway. This view illustrates the brushy character of the slopes in which the coal beds of the Raton formation crop out and the difficulty of following the lines of outcrop.



SECTIONS OF THE SUGARITE COAL BED.

Measured at the outcrop and in the mines. Numbers over the sections correspond to locality numbers on Plate I.

ite coal thick enough to induce the owners to prospect the bed. However, valuable deposits of coal similar to that developed in the Sugarite mine may yet be found at this horizon elsewhere, and for this reason the meager information regarding this coal southwest of Raton may be summed up as follows:

SUGARITE COAL, KOEHLER TO RATON.

The southernmost locality at which a definite record was obtained of coal at the approximate horizon of the Sugarite bed is in the prominent escarpment southeast of Van Houten, where the section given in detail on page 3 was measured at locality 139. Here a coal bed 2 feet 6 inches thick with shale above and below it was found 217 feet above the base of the Raton formation. As the conglomeratic sandstone at the base of the formation is here 133 feet thick the coal bed lies 84 feet above the highest conglomeratic sandstone, a position which corresponds closely with that of the Sugarite bed.

A bed 1 foot thick was penetrated by the drill 178 feet above the main coal bed at locality AA, in Willow Canyon, but no coal is reported at this horizon from drill prospect BB, in the same canyon, although a 1-foot coal bed was found there 103 feet above the main or Raton coal bed. These may possibly represent the same bed, the difference in thickness between them and the main bed being due to variations in the thickness of the Vermejo formation. Indications of coal were noted at about the same horizon farther north, especially in Cottonwood Canyon and near the mouth of Coal Canyon, but in both of these canyons the beds of the "Sugarite zone" have been greatly disturbed by intrusions of igneous rock, and it is not probable that valuable coal will be found here.

There are three beds of coal in this zone in Coal Canyon, at locality CC (see Pl. XVI), the thickest of which is 1 foot 8 inches, but their presence is not recorded at locality DD nor is coal known to occur in this zone beneath Potato Canyon unless the two 1-foot beds penetrated by the drill near the bottom of the hole at locality EE are in the "Sugarite zone," as suggested on page 141.

In Canadian River canyon at locality 189 several thin beds of coal were found in the lower part of the coal-bearing rocks, but all of them are lower in the section than would be expected for the Sugarite bed. Their stratigraphic relations are shown in the section described on page 74. In the north wall of Canadian River canyon coal was observed in many places at about the horizon of the Sugarite bed, but a relatively persistent sheet of igneous rock occurs near the same horizon and has destroyed the coal in most places. Coal which may be the Sugarite bed was found by the drill at locality A with igneous rock below it, and a bed 1 foot 3 inches thick with shale above and

below it was penetrated at a horizon considerably lower. Farther to the southeast a coal bed of considerable thickness crops out in the "Sugarite zone." At locality 203 it is 90 feet above the base of the Raton formation and at locality 204 it is 85 feet above it. At locality 207, south of Gardiner, 3 feet of coal with shale above and below it was found 74 feet above the base of this formation. Three thinner beds of coal are reported from the "Sugarite zone" at this locality. (See Pl. II, p. 12.) The occurrence of thin beds of coal in the several drill prospects farther to the north and west are perhaps sufficiently well shown on Plates XII and XVI, and attention need not be further called to them here.

A bed of impure coal that occurs not far from the horizon of the Sugarite bed was found at the outcrop in Seeley Canyon, west of Blossburg, 78 feet above the base of the Raton formation just north of locality 223. (See section on p. 87.) It is 3 feet thick and has shale above and below it. This bed may possibly be the Sugarite but is more likely to be the coal bed just described that occurs about 65 feet above the base of the Raton formation in the drill prospect at locality A.

In the opposite wall of Dillon Canyon, at locality 204, a coal bed that probably is the same as the bed just described occurs 85 feet above the base of the Raton formation. (See section on p. 82.) It consists of shaly coal 2 feet 6 inches thick and has shale above and below it. Another bed of coal or several thin layers separated by shale occurs 31 feet higher in the section. One of these coals probably represents the Sugarite bed, which is 80 feet above the base of the Raton formation where the drill penetrated it near Yankee. A good exposure of this coal was found in a cut on the Scenic Highway west of Raton, north of locality 252, where the following section of it was measured:

Section of coal bed north of locality 252, on Scenic Highway, west of Raton.

	Ft.	in
Shale.		
Coal		8
Shale	2	6
Coal	2	6
Shale.		
Total thickness of bed	5	8
Coal	3	2

Farther north, on the ridge above locality 256, the Sugarite bed is 3 feet or more in thickness but is not well enough exposed for detailed measurement.

SUGARITE COAL EAST OF RATON.

In the section measured near locality 261, described on page 93, three beds of coal were found in the "Sugarite zone." The thickest bed, which seems to be the Sugarite bed, has 1 foot 8 inches of coal

with shale above and below it and occurs about 95 feet above the base of the Raton formation. A 1-foot bed occurs 20 feet above it and a 10-inch bed 15 feet below it. Farther east surface indications of this bed were observed in so many places that the coal has practically been traced to the Sugarite mine, although the next definite measurement was made about a mile east of locality 261. It is 2 feet 8 inches thick in the ridge above locality 265, and in the gulch above locality 266 a bed of coal 83 feet above the base of the Raton formation, as measured by a Locke level, gave the following section:

Section of coal bed in gulch above locality 266.

	Ft.	in.
Shale.		
Coal		4
Shale		6
Coal		3
Bone		½
Coal	1	1
Shale.		
Total thickness of bed	2	2½
Coal	1	8

The Sugarite coal, 3 feet thick, with shale above and below it, lies 15 feet above this bed. These two beds were found east of Linwood Canyon at locality 333. The lower one is 2 feet thick, but the coal is impure. The Sugarite bed here contains 3 feet of coal of good quality and has shale above and below it. This bed thickens east of Linwood Canyon, and a surface measurement at locality 334, near the head of the first gulch east of this canyon, indicates a thickness of about 3 feet of coal, with shale above and below it. The bed is here somewhat higher in the section than it is at other localities because of the increased thickness of the basal conglomerate of the Raton formation. The section measured at this locality is as follows:

Section of rocks at locality 334, in gulch east of Linwood Canyon.

	Feet.
Sandstone and shale	20
Coal, Sugarite bed	3±
Shale and sandstone	16
Shale, carbonaceous, with 6-inch bed of coal	2
Sandstone	30
Sandstone and shale	22
Coal	1
Shale	30
Covered	6
Sandstone, conglomeratic, base of Raton formation	20
Unconformity.	
Shale, carbonaceous	2
Sandstone and shale.	
	152±

In the next gulch to the southeast another section was measured at locality 335 as follows:

Section of rocks at locality 335, east of Linwood Canyon.

[For graphic section see Pl. II, p. 12.]

	Ft.	in.
Shale.		
Coal, Sugarite bed	4	6
Sandstone and shale, in alternating layers	12	
Shale, carbonaceous, with a 6-inch bed of coal	3	
Sandstone and shale, in alternating layers	40	
Shale, not continuously exposed	20	
Sandstone, massive, rusty near the top, conglomeratic near the base	30	
Unconformity.		
Shale	1	
Sandstone, Trinidad.		
	110	6

Southeast of the last locality described the Sugarite bed was observed in several places, but for a distance of half a mile along the outcrop no measurement could be made. Farther east, however, this coal bed has been opened in several places. At locality 336 it has a thickness of 2 feet 7 inches. Farther north, at locality 337, it is 2 feet thick, and at locality 338 it is 2 feet 4 inches thick. This coal bed is so much thinner and differs so radically in character from the Sugarite coal bed, as represented by the sections presented below, that it is probably not the Sugarite bed but the bed which lies a few feet below the Sugarite and which locally contains considerable coal.

Still farther east, at locality 339, is the opening of a mine, now abandoned, known as the old Wagon mine because coal was transported by wagon from it to Raton. At this opening the coal is 5 feet 5 inches thick, with shale above and below it, but is slightly thinner in the mine. (See Pl. XVIII.) This mine was in operation in 1908, when the writer collected a sample of the coal for analysis. This sample was taken 1,800 feet from the mouth of the mine, which opened at locality 339, and includes coal from the lower bench 4 feet 7½ inches thick.

An opening of a still older abandoned mine was found nearly half a mile farther southeast of locality 340, but no information was obtained concerning it. The section in the south slope of Horse Mesa (Pl. XVI) was measured near this locality. At locality 341, on the west slope of a spur of Bartlett Mesa, and also on the east slope of this spur, at locality 342, good measurements of this bed were obtained. These measurements are shown in Plate XVIII. This coal bed was not found in the section measured on the ridge between these two localities, but is probably present in the unexposed interval at the altitude at which the Sugarite coal should be found. (See section on southeast point of Bartlett Mesa, Pl. XVI.) However, the thin

bed of coal below the Sugarite bed was found here 76 feet above the base of the Raton formation, as measured by Locke level. It is 3 feet thick, with shale above and below it.

In the west wall of the canyon of Chicorica Creek the bed was opened in several places on the outcrop, but later development in the Sugarite mine gave opportunity for more exact information as to thickness and character, and the measurements made by the writer in this mine will be used here in place of those made in the prospect opening at the outcrop. The points at which sections were measured are noted by number on the map (Pl. I), and the sections are shown on Plate XVIII.

Just north of locality 343, or 1,500 feet from the mouth of the mine, under nearly 500 feet of cover, a sample of the coal was collected for analysis by the writer on September 25, 1912. The results of this analysis are given as analysis 14791 in the table on page 244. The section of the bed measured at this locality is as follows:

Section of coal bed north of locality 343, in the Sugarite mine.

	Ft.	i.
Shale with thin seams of coal.		
Coal		4
Shale		1½
Coal (see analysis 14791)	5	1
Shale.		
Total thickness of bed	5	6½
Coal	5	5

At the end of the second right entry, at locality 346, the bed is cut by a normal fault that has a downthrow of 3 feet on the west. At the end of the first west cross entry, at locality 349, this fault was observed, but the amount of downthrow of the coal bed on the west of it had not been determined at the time of the writer's investigation.

Between localities 348 and 349 two well-marked faults cross this entry in a direction nearly due north. Each one has a downthrow of about 5 feet on the west. These faults were noted also in the two cross entries farther to the south. There are several thin beds of coal in this canyon below the main bed. One bed 1 foot 4 inches thick was found 10 feet above the Trinidad sandstone and a 6-inch bed 6 feet higher. There are surface indications of other beds, but their thickness was not obtained.

The Sugarite bed was opened in a prospect at locality, 350 west of Lake Alice, and the following section of it measured:

Section of coal bed at locality 350, west of Lake Alice.

	Ft.	in.
Shale.		
Coal		9
Shale		3
Coal	2	6
Shale		6
Coal	1	8
Shale.		
Total thickness of bed	5	8
Coal	4	11

This section indicates that the coal bed as shown in the mine holds its thickness for a considerable distance north of the Sugarite mine, as that mine was developed in 1912, but at that time the bed had not been found north of Lake Alice, probably because of the accumulation of surface débris but possibly in part also because of displacements by faulting. If the faults noted in the mine persist northward with direction unchanged they would reach the surface west of Lake Alice at the horizon where the coal might be expected to crop out. A downthrow of the beds to the west might render the tracing of the outcrop very difficult.

The northernmost exposure of the Sugarite coal bed found in the east wall of the canyon is at locality 351, near the outlet of Lake Alice. Farther south the character of the bed is best indicated by the measurements made within the mine, which are given as sections 352 to 360, inclusive, in Plate XVIII.

At a point slightly south of locality 355, or 1,200 feet from the mouth of the mine, the writer collected a sample of the coal for analysis on September 25, 1912. The results are given as analysis 14792 in the table on page 244. The sample represents the main bench at a point where this coal is 4 feet 11 inches thick. (See platted section 355, Pl. XVIII.)

Near the end of the entry, at locality 356, the bed is slightly disturbed by a fault, but the coal maintains essentially the same thickness and character that it shows farther to the west. However, the bed presents a somewhat different aspect in the first cross entry to the right. Also, the section of the bed shows more complexity and the coal is somewhat disturbed by a fault near the mouth of the mine. Farther east, at locality 358, a fall from the roof enabled the writer to measure a more complete section than was obtained elsewhere in the mine. It is as follows:

Section of coal bed at locality 358, in Sugarite mine.

	Ft.	in.
Shale.		
Coal	1	1
Shale	1	6
Sandstone		8
Shale	1	6
Coal		6
Bone		2½
Coal		2½
Bone		2½
Coal	1	1
Shale.		
Total thickness of bed	10	11½
Coal in lower bed	5	9½

Near the end of this entry the coal bed is affected by rolls and "pinches," but the bed was found undisturbed at locality 359, where the section under this number in Plate XVIII was measured. The higher bed of the foregoing section is here present but was not exposed well enough to be measured.

A prospect entry was started in the gulch south of the main mine and run in on the coal bed about 800 feet. This entry was abandoned at the time of the writer's investigation because of the irregularities of the bed due to faulting and other movements of the rocks. A section of the coal bed measured in this entry is given as 361 on Plate XVIII.

In the recent extensions of the mine beyond the localities originally examined no new features have been developed, and the sections already described adequately represent the bed over the whole area mined at Sugarite.

Several measurements were made at the outcrop south of the mine where the bed is regular in thickness and character for a considerable distance, but a section measured at locality 362 (Pl. XVIII) shows that the main bench of coal is thinner there than at locality 361, and the shale parting above it has increased to such an extent that the upper bench of coal could not be mined to advantage. A section of the rocks between the Sugarite coal bed and the Trinidad sandstone was measured at locality 363 as follows:

Section of rocks at locality 363, in east wall of canyon of Chicorica Creek.

		Ft.	in.
Shale.			
Coal	Coal, Sugarite bed	1	1
Shale	Coal, Sugarite bed	3	
Coal	Coal, Sugarite bed	3	4
Shale and sandstone		40	
Coal		1	8
Shale		30	
Sandstone		9	
Shale		2	
Coal			8
Shale		9	
Trinidad sandstone.			
		99	9

The coal bed continues without notable change to locality 364 and east of the Maxwell land-grant line to the mouth of the old Hartsel mine, which was operated for a short time in 1895. There are several exposures of the coal bed near the old mine, and though the main bench of coal appears to be relatively regular the thin benches above it are variable. The main entry of the old mine was accessible for only 100 feet at the time of the writer's investigation. The best exposed face of the bed, 50 feet from the opening, was measured as follows:

Section of coal bed at locality 364, in old Hartsel mine.

	Ft.	in.
Shale.		
Coal		11
Shale	3	
Coal, shaly		6
Shale, carbonaceous		6
Coal (see analysis 6285, p. 244)		9
Shale		1½
Coal (see analysis 6285)	2	10
Shale.		
Total thickness of bed	8	7½
Coal	5	

The lower two benches were cleared of weathered coal, and a sample of the fresh coal was taken for analysis by the writer on July 21, 1908. The results are given as analysis 6285 in the table on page 244. In another opening, 175 feet north of the old mine entry, the main bench of coal is 3 feet 1 inch thick. The bed seems to have been considerably disturbed by the faulting and crushing of the rocks, and it has been reported that the mine was abandoned because of the unfavorable physical conditions encountered. A section in Plate XVI (p. 152) was measured from this locality to the top of Horse Mesa. Two thin beds of coal were found here below the Sugarite bed. One near the base of the coal-bearing rocks is only 8 inches thick, but the second one, 52 feet higher, is 1 foot 8 inches thick, with shale above and below it.

The mouth of another abandoned mine on the Sugarite bed is about 1,500 feet east of the Hartsel mine. It is locally known as the old Meredith mine. Little was learned of it, but the bed as measured at the mouth of the old entry is shown as section 365. The coal bed here exposed seems to be only the lower part of the bed examined at the Hartsel mine, but neither at the old Meredith mine nor farther east were the upper benches of coal seen. The lower bench thins somewhat but extends eastward as a persistent bed.

At locality 366 a coal bed 2 feet 3 inches thick with shale above and below it was found at a horizon that indicates the Sugarite bed. The apparent absence of coal above it renders it probable that this is the highest coal of the "Sugarite zone" and therefore the Sugarite bed.

North and east of this locality few places were found where satisfactory measurements could be made of the Sugarite coal bed. A thin bed of coal was found at this horizon when the old incline (the southernmost one was mapped) to the Yankee mine was built, but no record of its thickness was preserved. The writer also noted its occurrence at the outcrop in the gulch northeast of this incline, but the thickness of the coal was not ascertained.

In the next gulch farther north, at locality 367, there is an opening on a coal bed 110 feet above the base of the Raton formation, as measured by Locke level, a distance that suggests the Sugarite bed, although this bed, unlike the Sugarite bed at neighboring localities, occurs underneath a massive sandstone. The section at this locality is as follows:

Section of coal bed at locality 367, north of the Yankee mine.

	Ft.	in.
Shale.		
Coal		4½
Shale		½
Coal		2
Shale		½
Coal	1	6
Shale.		
Total thickness of bed	2	1½
Coal	2	½

Another bed of coal 1 foot thick occurs in this gulch 90 feet lower than the bed just described.

In the canyon south of the Reynolds mine (locality 594) a considerable thickness of coal was found at locality 368, about 100 feet above the base of the Raton formation. but the bed was not exposed well enough to obtain details of it. However, farther east, at locality 369, the Sugarite coal is well exposed in the east wall of the canyon and there shows a thickness of 2 feet 6 inches of coal with shale above and below it. This bed was measured at the surface in the gulch farther south, at locality 370, where it is 2 feet 4 inches thick, and at locality 371, where it is 2 feet 6 inches thick. At locality 372 the Sugarite bed is 105 feet above the base of the Raton formation. Another bed of coal 1 foot 2 inches thick occurs 21 feet below this bed at this locality. Near locality No. 372 a coal bed was found at an altitude appropriate for the Sugarite coal, with the following section:

Section of coal bed near locality 372, south of the Reynolds mine.

	Ft.	in.
Coal	2	
Shale	1	
Coal	1	11
Shale		4
Coal		2
Shale.		
Total thickness of bed	5	5
Coal	4	1

However, this bed of coal seems to thin out in some places far southeast of locality 372, where much carboniferous shale was found in the "Sugarite zone" but no coal beds of any considerable thickness. The presence of thick coal in this zone farther to the southeast in Rathbun and San Isidro canyons indicates that the beds become thicker again to the east.

In the east slope of Horseshoe Mesa, at locality 373, a landslide has exposed the rocks, including three coal beds of the "Sugarite zone." The higher one, 3 feet 2 inches thick, with shale above and below it, is probably the Sugarite bed, as it is 102 feet above the base of the coal-bearing rocks. The position of this bed east of Barilla Mesa was found to be 100 feet above this base in a drill hole put down on the slope of the mesa near the head of Rathbun Canyon. A bed of coal 1 foot thick was found 40 feet below the higher one and a third bed 1 foot 1 inch thick still lower. In no place farther north were these coal beds exposed sufficiently well to obtain any reliable measurements of their thickness.

South of Rathbun Creek indications of coal were seen at the outcrop in several places, but in only one place, at locality 375, in the gulch near the head of San Isidro Canyon, was an exposure found at which a satisfactory measurement could be made. Near this locality a mine was opened in 1903 and some coal was taken out by Frederick Scoop for local use. During the next few years an entry was driven in on the bed about 300 feet. This bed is probably the Sugarite coal. Mr. Scoop reports that the coal is 3 to 4 feet thick, but the roof consists of soft shale, and "falls" from it were troublesome. The mine was inaccessible at the time of the writer's investigation, but the bed was well exposed in the gulch east of the old mine. Here a recent flood had cleared away the brush and surface débris, exposing a fresh face of the coal. A short section was measured at this locality. From the main coal bed to the top of the mesa the rocks are perfectly exposed, but below this bed the brushy character of the surface renders the thicknesses as measured somewhat doubtful. The section is as follows:

Section at locality 375, in north rim of Johnson Mesa, in San Isidro Canyon.

	Ft.	in.
Basalt	30+	
Sand and gravel, cemented	70	
Unconformity by erosion.		
Sandstone, cliff-making	10	
Not exposed	34	
Sandstone, cliff-making	25	
Coal	1	4
Sandstone and shale in alternating layers	41	

	Ft.	in.
Shale	17	
Coal (see analysis 6284, p. 244)	4	1
Shale	1	1
Coal, bony		2
Shale	6	
Sandstone	2	
Shale	8	
Sandstone	12	
Shale, sandy	15	
Sandstone, massive	15	
Shale, not well exposed	40	
Sandstone	3	
Shale, mostly covered	29	
Sandstone (Trinidad).		
	363+	

The exposed surface of the main coal bed appeared fresh, and waterworn pebbles of the coal derived from it were found in the stream bed half a mile or more below the exposure. The face of the bed was cleared of weathered coal to a depth of about 2 feet and a sample taken for analysis by the writer, on July 15, 1908. The results are given as analysis 6284 in the table on page 244. The sides of the mesas are so thickly covered with brush and slide rock that good exposures in this part of the field are rare, and the coal bed was found undisturbed in only one other place in San Isidro Canyon. In the east slope of the mesa half a mile northwest of the Scoop mine, at locality 374, it is 3 feet thick, with shale above and below the coal. The same character of surface was found in the northern slope of Johnson Mesa, farther to the west. However, at locality 376, south of Yankee, an old mine, locally known as the old McClafferty mine, was opened on the Sugarite bed many years ago. The coal at the mouth of this old mine is 2 feet 3 inches thick, with shale above and below it, but no information was obtained of the character of the coal in the mine.

No place was found for a considerable distance southwest of this locality where a measurement of the Sugarite coal bed could be made, but this coal is exposed in the western slope of Johnson Mesa, at locality 377. A thickness of 5 feet of coal in the Sugarite bed at this locality has been reported, but the writer found no place where this measurement could be verified. A little farther south, however, at locality 378, the coal is 2 feet 4 inches thick, with shale above and below it.

Section near locality 377, at the west end of Johnson Mesa.

	Ft.	in.
Basalt	250	
Sand and cemented gravel	45	
Unconformity by erosion.		
Not exposed	25	
Coal		2
Shale, poorly exposed	15	
Sandstone	15	
Sandstone, coarse, friable, thin bedded	40	
Not exposed	125	
Coal	1	
Shale	34	
Sandstone, cliff-making	32	
Shale and sandstone in alternating layers	10	
Shale	2	
Coal		2
Shale		3
Coal	1	
Shale	1	
Coal	1	6
Shale, not well exposed	40	
Sandstone	5	
Shale, carbonaceous in places	28	
Sandstone, cliff-making	38	
Covered	15	
Coal	1	6
Shale, not continuously exposed	35	
Sandstone, massive, cliff-making	52	
Covered	22	
Sandstone, massive, cliff-making	28	
Shale	10	
Sandstone, massive, cliff-making	40	
Shale and sandstone in alternating layers	50	
Sandstone	6	
Shale	10	
Coal	5 (?)	
Shale	15	
Sandstone	2	
Shale and sandstone in alternating layers	45	
Sandstone, conglomeratic, brown	15	
Unconformity by erosion.		
Trinidad sandstone, containing the fossil sea weed *Halymenites major*	113	
Pierre shale.		
	1,174	1

A thin bed of coal that may be the Sugarite bed crops out in the south slope of Johnson Mesa in several places, but the full thickness of coal was not certainly exposed in any one of them. In the west wall of Hunter Canyon, at locality 285, the rocks from the Trinidad sandstone to the top of the mesa are fairly well exposed, and the section given below was measured there:

Section at locality 379, in Hunter Canyon.

	Ft.	in.
Basalt	50±	
Sand and gravel, partly consolidated	30	
Coal		6
Shale	3	
Sandstone, massive, cliff-making	20	
Shale with thin beds of coal	50	
Sandstone	3	
Shale		6
Coal	1	6
Shale, carbonaceous	2	
Shale with thin beds of sandstone not continuously exposed	50	
Sandstone (Trinidad).		
	210±	

The coal at this locality was crushed and is probably thicker than the section shows. A bed of coal 2 feet 6 inches thick was found in the brush-covered slope of the mesa half a mile northwest of locality 379. This may be the Sugarite coal. As the Sugarite bed is eroded east of locality 375 and east of Hunter Canyon, at locality 379, but crops out in the slopes of Johnson Mesa west of the localities, the bed is probably continuous under Johnson Mesa west of a line drawn from Hunter Canyon northeastward to the northern rim of the mesa about a mile east of the Scoop mine (locality 275). The eastward extent of the coal can not now be more definitely determined.

MINES IN THE SUGARITE COAL BED.

SUGARITE MINE.

Several small mines mentioned in the foregoing descriptions of localities have been opened from time to time in the Sugarite coal bed and operated for local use. The last of these was abandoned when the present Sugarite mine was opened in 1912. The new mine is located at Sugarite, about 4 miles northeast of Raton, with which it is connected by railroad. The geographic and stratigraphic relations of the bed have already been described. From the measured thicknesses of the coal it is obvious that the Sugarite mine is located where the coal bed attains its maximum known thickness. From this maximum the thickness decreases markedly along the outcrop to the west and in a short distance the bed becomes too thin for profitable mining under present conditions. The same is probably true to the north and east, but back from the outcrop this can be tested only by the drill and at the time of this writing only one record is available—that of the hole in the eastern slope of Horse Mesa—where the main bench of coal in the Sugarite bed is 2 feet 9 inches thick.

The developed area in 1919 is indicated on the accompanying map, and the character of the bed in the mine has been described in connection with the outcrop measurements. (See Pl. XVIII, p. 152.)

The roof of the mine differs considerably in character from place to place. In some places the upper thin bench of coal is left to serve as the roof and in others this bench is removed, and in these places the roof consists of relatively soft shale that has a tendency to fall in irregular masses.

The coal is a bright, black bituminous coal with vitreous luster. Although the other coals of this field both older and younger than the Sugarite coal are of coking quality, the practical tests in the coke ovens that have thus far been made indicate that the Sugarite coal does not coke. It contains a large quantity of resin that occurs in irregular streaks and lumps throughout the bed. The coal burns freely, without notable clinker, and for this reason it is popular as a domestic fuel. Probably the large amount of resin renders it appreciably more valuable as a domestic fuel than it would be without the resin. The coal is not seriously affected by exposure to the weather and is shipped without notable deterioration. The joints in the coal are well developed, especially west of Sugarite Canyon, where the major cleat faces are 6 to 10 inches apart, and because of them no shooting is necessary in mining the coal. On the east side the cleat faces are not so well developed, and the coal is shot from the face of the bed. Its quality is indicated by the four analyses of coal from this mine given on page 244.

The floor of the mine is soft shale and "heaves" badly in some places, especially where the shale is wet.

The Sugarite mine is a double entry drift mine with openings on both sides of the canyon (see Pl. XVII, *B*, p. 152) and so located that the coal is lowered from the mouth of the mine on either side over an incline and finally through the tipple to the railway cars below. The mine is worked by the room-and-pillar system. It is ventilated by electrically driven fans on side of the canyon and is timbered with props on which are placed caps or cross-bars as needed. The coal is undercut and wedged or shot down. Chain machines for undercutting had been installed in 1913 but were not yet in operation. Monabell powder is used and is handled entirely by shot firers. No gas has been encountered in the mine and open lights are used.

Mules are used in the mine for gathering the loaded cars but electric motors are used for hauling in the main entries. The two inclines from opposite sides of the canyon meet at the tipple built at the bottom of the canyon. This tipple is fitted with perforated shaker screens, box-car loaders, and other appliances. The coal is separated into lump, about 37 per cent; nut, 20 per cent; pea, 20 per cent; and slack, 23 per cent. The slack is used as a steam coal,

but the other sizes are used mainly for domestic fuel. At the time of investigation in 1913 the mine was producing about 500 tons of coal per day and had an estimated maximum capacity of 1,500 tons.

WAGON MINE.

The only other mine on the Sugarite bed for which details were obtained is the old Wagon mine, formerly known as Sugarite mine No. 2 and now abandoned, which opens at locality 339. It was opened in 1902 and was worked continuously from that time until the new Sugarite mine was opened in 1912. The coal near the Wagon mine will now be taken out through the new Sugarite opening.

The roof shale in this mine has many impressions of leaves and tree trunks, large palm leaves being especially abundant. The roof material consists of soft clay shale, which falls readily, sometimes in plates but often in masses known as "pots." These pots are usually conical in form, the apex extending upward into the roof shale. They are bounded laterally by slicken surfaces, and the apex usually consists of bright glistening coal, hard and brittle, breaking with an irregular hackly surface. On the cleavage faces of this coal are "bird's-eye" markings which have a radial structure. (See Pl. VIII, *C*, p. 48.) This coal is in places granular and is much harder and brighter than the coal of the main bed. Many rolls and slickensides were encountered in the mine, presumably formed by the movements of the rocks under pressure. More or less movement was going on constantly in the mine during the time it was operated, probably caused by the yielding of the soft shale under pressure. These movements resulted in caving sides, broken props, and other damage. The floor of the mine consists of shale.

The coal of the main bed is black, bituminous, compact, and relatively hard and contains much resin. It has bright luster, banded texture, and conchoidal fracture. There are conflicting reports as to its coking quality. It seems to coke to some extent but not well enough to make the coking practicable. The heating power is less than that of the Vermejo coals, but the Sugarite coal burns freely and before this mine was abandoned its product was regarded as superior for domestic purposes. It did not slack badly on exposure to the weather and was transported without serious deterioration.

A 4-foot dike of basalt which was encountered in the mine trends N. 60° W. and cuts across the bed, coking the coal on either side. The coke is 18 inches thick in columns perpendicular to the sides of the dike, and a zone of granular coke a few inches thick occurs between the columnar portion and the unchanged coal beyond. Another dike 1 foot thick crosses the main entry 100 feet farther

from the opening. This dike has coke 6 inches thick on both sides. The bed has an irregular dip of about 1° in a direction N. 80° W. and is not badly faulted, although slight displacements occur and rolls are numerous. Cleat faces are well developed about 4 inches apart and trend N. 8° W. The bed is somewhat upturned near the outcrop, the maximum dip being about 3°. This local upturning is noticeable for about 75 feet from the mouth of the mine. Farther from the surface the dip is more regular. Also, the thickness of the coal is greater near the surface than it is farther under cover, the main bench being 5 feet 5 inches thick at the outcrop and only 4 feet 7½ inches thick 1,800 feet from the mouth of the mine, where the following section was measured:

Section of coal bed in old Wagon mine 1,800 feet from mouth.

	Ft.	in.
Shale.		
Coal		2
Shale		4
Coal		6
Shale, with thin seams of coal		6½
Coal (see analysis 6286, p. 244)	4	7½
Shale.		
	6	2

A sample of this coal was collected for analysis at the point where the foregoing section was measured, 1,800 feet from the mouth of the mine, and represents the main bench of coal. It was taken by the writer, July 23, 1908. The result is given as analysis 6286 in the table on page 244.

COAL BEDS OF UPPER COAL GROUP.

SOUTHWESTERN PART OF BRILLIANT QUADRANGLE.

In the southwestern part of the Brilliant quadrangle the upper coal beds outcrop in many places, but with few exceptions the exposures are so poor that measurements of the beds made at the surface have little value. The altitude of the beds and their character as shown by the surface exposures indicate that the group as known in the developed area farther to the northeast occurs in this part of the quadrangle and that when the beds are prospected systematically some of them will be found to contain coal of economic value. A few of the best exposures are indicated on the accompanying map by locality numbers, and the sections measured at these localities are described as follows:

In the extreme northern part of the Koehler quadrangle, in the east fork of Saltpeter Creek, a bed of coal is exposed in the channel of the stream, and the same bed was opened half a mile farther west. It was measured as follows:

Sections of coal bed on Saltpeter Creek.

	East Fork.	One-half mile west of locality on East Fork.
Shale.	Ft. in.	Ft. in.
Coal	8	1
Shale	1	1
Coal	1 3	1
Shale	3	4
Coal	11	9
Shale.		

Surface croppings in several places indicate that this bed of coal underlies the highlands in the northwestern part of the Koehler quadrangle, but it has not been systematically prospected.

It is the lowest bed of coal of any commercial value in the upper coal group. One or perhaps two coal beds, each less than a foot thick, lie a few feet below the one measured. The absence of coal between these beds and the Raton coal was demonstrated by a diamond-drill hole put down in Saltpeter Canyon 1½ miles south of the northern border of the Koehler quadrangle.

In Saltpeter Canyon, in the extreme southwestern part of the Brilliant quadrangle, at locality 380, the same bed of coal is rather poorly exposed and the following measurement was made:

Section of coal bed in Saltpeter Canyon, at locality 380, in Brilliant quadrangle.

	Ft.	in.
Sandstone.		
Coal	1	1
Shale		2
Coal		5
Shale		3
Coal		6
Shale.		
Total thickness of bed	2	5
Coal	2	

This coal bed has been surveyed in the several branches of Caliente Creek west of the area shown on the map for a distance of several miles and opened in seven places. The prospects indicate that it is a bed of considerable commercial value. It doubtless underlies the highlands in the southern part of the Brilliant quadrangle and connects with one of the thick beds in Potato Canyon.

A bed about 150 feet higher than the one just described was opened at locality 381, where the following section was measured:

Section of coal bed at locality 381, in Brilliant quadrangle.

	Ft.	in.
Coal	1	8
Shale		8½
Coal	2	7

A bed at nearly the same elevation is poorly exposed at locality 382, where the following section was measured:

Section of coal bed at locality 382, in Brilliant quadrangle.

	Ft.	in.
Shale.		
Coal		6
Shale		4
Coal	1	3
Shale.		
Total thickness of bed	2	1
Coal	1	9

Near the western boundary of the quadrangle a bed of coal crops out in the wall of Deadhorse Canyon, at locality 383. The following measurements were made at the outcrop:

Section of coal bed at locality 383, in Deadhorse Canyon.

	Ft.	in.
Shale		
Coal	2	
Shale	6	5
Coal		11
Shale.		

A mile to the southeast, at locality 384, another exposure occurs at about the same elevation as at the last locality, but the character as shown by the following measurements indicates that the bed is probably not the same.

Section of coal bed at locality 384, in Brilliant quadrangle.

	Ft.	in.
Shale.		
Coal		6
Shale		3
Coal	1	3
Shale		3
Coal		2
Shale		1
Coal		5
Shale.		
Total thickness of bed	2	11
Coal	2	4

Farther east, in Crow Canyon and its tributaries, the exposures are better, and indications of coal were found in many places. However, the beds must be opened before much definite information concerning their character can be obtained. At locality 385 a thin bed was measured as follows:

Section of coal bed at locality 385, in Crow Canyon.

	Ft.	in.
Shale.		
Coal		6
Shale		4
Coal	1	3
Shale.		
Total thickness of bed	2	1
Coal	1	9

About 1½ miles to the northwest, at locality 386, a thick but very shaly bed is well exposed in the bottom of Crow Canyon and was measured as follows:

Section of coal bed at locality 386, in Crow Canyon.

	Ft.	in.
Shale.		
Coal		11
Shale		1
Coal		10
Shale		5
Coal		6
Shale		6
Coal		11
Shale		5
Coal		3
Shale		1
Coal	1	
Shale		7
Coal	1	5
Shale		3
Coal		3
Shale		2
Coal		4
Shale		7
Coal		9
Shale		4
Coal		11
Coal, bony	1	5
Shale.		
Total thickness of bed	12	11
Coal	9	6

At locality 387, about a mile farther upstream and 125 feet stratigraphically higher, as indicated by Locke level measurement, another bed is well exposed, and the following section was measured:

Section of coal beds at locality 387 in Crow Canyon.

	Ft.	in.
Shale.		
Coal		9
Shale	2	6
Coal		6
Shale		3
Coal		2
Shale		7
Coal	1	1
Shale	6	
Coal		8
Shale.		
Total thickness of bed	12	6
Coal	3	2

Still farther upstream, at locality 388, and at a horizon about 200 feet stratigraphically above the bed last described a coal bed was measured as follows:

Section of coal bed at locality 388, in Crow Canyon.

	Ft.	in.
Shale.		
Coal	1	2
Shale	1	9
Coal		4
Shale	1	
Coal		4
Shale		1
Coal	1	
Shale		1
Coal		6
Shale.		
Total thickness of bed	6	3
Coal	3	4

Some thin beds of coal were found at higher horizons, but none of them seem to have much economic value.

Farther east, in Little Crow Canyon, two exposures of coal were found at about the same altitude, but the following sections indicate that they are probably different beds. The first one, at locality 389, gave the following measurements:

Section of coal bed at locality 389, in Little Crow Canyon.

	Ft.	in.
Sandstone.		
Coal	1	5
Shale	1	
Coal		8
Shale	1	5
Coal	3	9
Shale.		
Total thickness of bed	8	3
Coal	5	10

The second section was measured at locality 390, where the coal is as well exposed in the bed of the canyon as it would be in a prospect opening. The character of the bed at this locality is indicated by the following section:

Section of coal bed at locality 390, in Little Crow Canyon.

	Ft.	in.
Shale.		
Coal		1
Shale		10
Coal	1	5
Shale		10
Coal		10
Shale		7

	Ft.	in.
Coal		8
Shale		10
Coal	1	5
Shale.		
Total thickness of bed	7	6
Coal	4	5

A thin bed of shaly coal lies 15 feet above the beds in the last-described section, and 20 feet higher a bed having a thickness of 3 feet 4 inches of clean coal was found, with shale above and below it. About half a mile farther up the right branch of Little Crow Canyon and at an altitude of 100 feet above the bed last mentioned a coal bed was measured at its outcrop, at locality 391, as follows:

Section of coal beds at location 391, in right branch of Little Crow Canyon.

	Ft.	in.
Shale.		
Coal		10
Shale		3
Coal		9
Shale	1	3
Coal		11
Shale	4	3
Coal		5
Shale.		
Total thickness of bed	8	8
Coal	2	11

In Dry Canyon the lowest bed of any considerable thickness was found at an altitude of about 7,150 feet and was measured at locality 392 with the following results:

Section of coal bed at locality 392, in Dry Canyon.

	Ft.	in.
Shale.		
Coal		7
Shale		7
Coal		8
Shale		4
Coal		6
Shale		5
Coal		10
Bone		1
Coal		11
Shale	2	
Coal		8
Shale	3	
Coal	1	
Shale.		
Total thickness of bed	11	7
Coal	5	2

This bed of coal lies above massive sandstones known locally as the "barren series;" hence the coal is the lowest of the upper group of coal beds.

Farther up Dry Canyon coal was found at several horizons. A bed was measured on the outcrop at localities 393 and 394, with the following results:

Sections of coal beds at localities 393 and 394, in Dry Canyon.

	Locality 393.	Locality 394.
	Ft. in.	*Ft. in.*
Shale.		
Coal	2 3	3 1
Coal, bony	10	8
Shale.		
	3 1	3 9

Another bed a few feet higher than the last one described is exposed at locality 395, where it was measured as follows:

Section of coal bed at locality 395, in Dry Canyon.

	Ft.	in.
Shale.		
Coal		6
Shale	2	11
Coal	1	7
Shale		8
Coal		7
Shale.		
Total thickness of bed	6	3
Coal	2	8

A coal bed 200 feet or more stratigraphically above those just described, but half a mile farther up the canyon, is exposed at locality 396, where the following section was measured:

Section of coal bed at locality 396, in Dry Canyon.

	Ft.	in.
Sandstone.		
Shale	1	2
Coal		11
Shale		2
Coal		6
Shale		8
Coal		9
Shale		7
Coal		2
Shale	4	
Coal	1	2
Shale.		
Total thickness of bed	10	1
Coal	3	6

No good exposures of coal were found in the east branch of Dry Canyon, but on Antler Creek, in the fork of the canyon, at locality 397, a bed of coal was measured at its outcrop as follows:

Section of coal bed at locality 397, on Antler Creek.

	Ft.	in.
Shale.		
Coal		10
Coal, bony		4
Shale	6	6
Sandstone	3	5
Shale		8
Coal	1	
Shale	1	8
Coal		1
Shale		3
Coal		1
Shale.		
Total thickness of bed	14	10
Coal	2	4

These beds of the upper group of coals doubtless underlie the highlands between Crow Canyon and North Willow Canyon. Some of them have been penetrated by the drill in a prospected area near the Willow mine, and their presence is indicated at the surface in many places, but in few places were the coals sufficiently well exposed to show the true character of the bed. A good exposure was found of one of the highest of these coal beds at locality 398, near the top of the ridge north of North Willow Canyon, and the following measurements of it made:

Section of coal bed at locality 398, in ridge north of North Willow Canyon.

	Ft.	in.
Shale.		
Coal	1	3
Shale		1
Coal	1	4
Shale		6
Coal	1	7
Shale	2	
Coal		6
Shale.		
Total thickness of bed	7	3
Coal	4	8

Another bed, fairly well exposed, was found at locality 399, where the following section was measured:

Section of coal bed at locality 399, in ridge north of North Willow Canyon.

	Ft.	in.
Sandstone.		
Coal	1	
Shale	3	8
Coal	1	10
Shale.		
Total thickness of bed	6	6
Coal	2	10

The number of beds of coal in the upper group in this region and their stratigraphic position and thickness are best indicated by the

record of the drill hole put down at locality CC (see Pl. XVI) in the south fork of Coal Canyon. Locality CC marks the southern limit of the area in which the coal beds of the upper group have been carefully prospected. The lower three beds of the upper coal group contain coke, but there is little in the record to indicate why these coals have been coked. The thin sheet of igneous rock penetrating them seems inadequate. The thickness of the coals represented by the coke is not known, but several beds exposed in Coal Canyon farther north at altitudes that indicate beds represented by the coke of the drill record contain coal sufficiently thick to show that they may represent the lower coals of the group in areas still farther north, where the lowest bed of commercial value is the Tinpan coal. This bed is 674 feet above the Trinidad sandstone where it was penetrated by the drill at locality FF, in Tinpan Canyon. The thickest or 4-foot bed in Coal Canyon is about the same distance above the Trinidad sandstone, which suggests that it, rather than the lower beds, may represent the Tinpan coal. This relation can be determined only by careful tracing of the beds and prospecting at short distances.

PROSPECTED DISTRICT ON CANADIAN RIVER.

GENERAL FEATURES.

Some of the coals of the upper group are well exposed in Coal Canyon and its tributaries, but they have not been systematically prospected nor have their relations to the better-known beds farther north in Potato Canyon been definitely determined. In the main branch of Coal Canyon, about a mile north of drill hole CC, four coal beds were found at altitudes ranging from 7,250 to 7,450 feet. Only the highest of these is well enough exposed to allow of satisfactory measurement. At the fork of the canyon, at locality 400, the surface débris had been washed away, making a clean exposure of the coal bed, which has the following section:

Section of coal bed at locality 400, in Coal Canyon.

	Ft.	in.
Sandstone.		
Coal	1	4
Shale		5
Coal		3
Shale		6
Coal		10
Shale		7
Coal		6
Shale		10
Coal		5
Shale		9
Coal	1	8
Shale.		
Total thickness of bed	8	1
Coal	5	

The character of this bed as shown by the foregoing section is quite different from that of any of the beds penetrated by the drill at locality CC in the south branch of the canyon, and the altitude, 7,450 feet, indicates that it should outcrop 75 feet or more above the point where the drill hole was started. Furthermore, this is not the highest bed of commercial value in this region. The most valuable bed found in several places farther to the north occurs at altitudes close to 7,500 feet. This highest thick bed was not seen in Coal Canyon, but the beds lie nearly horizontal in this part of the field, and it is probable that the thick bed may yet be found there. Two of the lower beds of the upper group were found in the south wall of the canyon east of the locality last described. The first bed, which has a thickness of 2 feet 2 inches of coal, with shale above and below it, was found at locality 401, at an altitude of 7,350 feet, as indicated by aneroid barometer. At locality 402, and also at a horizon about 35 feet lower than that at locality 401, a thickness of two feet 1 inch of crushed coal was found, but this may not represent the full thickness of the bed. Other coal beds outcrop at lower horizons, but no good exposures of them were found. These are probably the thin beds penetrated by the drill at prospect CC, in the lower part of the upper zone of coal-bearing rocks.

A mine was opened many years ago on one of these beds of coal, but which one is not known nor can the location of the mine be indicated now on the map. It supplied coal for a sawmill that was formerly located near the fork of the canyon east of locality 402. The coal bed at the old mine is reported as follows:

Section of coal bed at old mine near mouth of McClellan Canyon.

	Ft.	in.
Coal	1	6
Shale		2
Coal	2	1
Total thickness of bed	3	9
Coal	3	7

A drill hole was put down at the junction of Coal and McClellan canyons, at locality DD. It was started at an altitude of 7,161 feet and therefore below the horizon of any of the thick beds of coal of the upper group. No bed was found that can be correlated with the "Sugarite coal," and intrusive igneous rock was found at the horizon of the Raton coal.

In McClellan Canyon the several lower beds of the upper group of coals found in Coal Canyon were observed, but no good exposure of any of them was found. However, at locality 403 a bed was well exposed in the south wall of the canyon at about the same altitude as that of the highest one described in Coal Canyon at locality 400,

and its character as well as its altitude indicates that it is the same bed. The measurements of this bed are as follows:

Section of coal bed at locality 403, in McClellan Canyon.

	Ft.	in.
Sandstone.		
Shale	1	3
Coal		8
Shale		6
Coal		8
Shale	2	
Coal		3
Shale		8
Coal		5
Shale	1	4
Coal		10
Shale		4
Coal		7
Shale	1	
Coal		3
Shale.		
Total thickness of bed	10	9
Coal	3	8

A coal bed 100 feet or more above the one just described is exposed in McClellan Canyon, at locality 404, where a prospect entry was run in on it several years ago. The entry was caved at the time of the writer's investigation, but the bed was exposed well enough at the entrance to measure it with reasonable accuracy, as follows:

Section of coal bed at locality 404, in McClellan Canyon.

	Ft.	in.
Shale.		
Coal	5	
Shale		7
Coal	1	5
Shale.		
Total thickness of bed	7	
Coal	6	5

Two lower beds of coal were found near this thick one, but at no place was a sufficient thickness of coal exposed to indicate that they are economically valuable.

The coal beds exposed in McClellan Canyon doubtless extend through the highlands to Potato Canyon, where there are four or more beds of coal that are likely to be commercially valuable. Only two of these beds have been systematically prospected in Potato Canyon and their outcrop lines surveyed. This work was done by the coal company before the topographic map was made. Most of the prospect openings have caved since they were made, and the measurements can not now be verified without reopening the prospects. Also, the outcrop lines as traced by the engineers can not in some places be satisfactorily adjusted to the topography. For these reasons the old prospects are located only approximately on the accompanying map (Pl. I).

The higher of the two prospected beds, which is known as the Potato Canyon coal, is approximately 115 feet above the lower one, which is believed to be the southward extension of the Tinpan coal that is mined at Brilliant. The sections measured at the old prospects are platted on Plate XIX. From these sections it may be seen that although there is a large amount of coal in the Potato Canyon bed, it occurs as numerous thin benches that are separated by partings of shale.

POTATO CANYON COAL AND HIGHER BEDS.

Near the head of the first south side gulch in Potato Canyon, at locality 405, a coal bed that was opened showed three benches of coal separated by thin partings of shale. In the west wall of this gulch three other openings were made on this bed. In the first two openings the bed has essentially the same character as that shown in section 405, but at locality 408 the bed is decidedly thicker and the lower shale parting has thickened to 11 inches.

In the second south side gulch four openings were made in this bed. The first opening, at locality 409, shows five benches of coal and the other openings four to six benches, although the bed as a whole is not notably thicker. Coal was found in this gulch at eight horizons ranging in altitude from 7,200 to 7,550 feet, but no good measurements were made on any bed except the Potato Canyon coal and the lower bed, which is described below.

In the main canyon, at locality 413, a bed of coal, which is supposed to be the Potato Canyon coal, although there is some doubt of this correlation, is 6 feet 3 inches thick and has only two shale partings. It differs somewhat in thickness from place to place, but the three benches of coal seem to be persistent throughout a considerable area south of the canyon, as indicated by sections 413 to 417, inclusive. At the last-mentioned locality, where the bed is well exposed in a prospect entry, the coal is separated above by 3 feet of shale from a massive sandstone, which seems to occur above the coal throughout the district between Potato and Canadian River canyons.

A prospect opening was made in this coal bed in 1893 at a point northeast of locality 414, but not definitely located on the map (Pl. I). The following measurements are reported from this prospect:

Section of coal bed near locality 414, in Potato Canyon.

	Ft.	in.
Shale:		
Coal	2	2
Shale		1½
Coal		9
Shale		4
Coal	1	5
Shale.		
Total thickness of bed	4	9½
Coal	4	4

At the junction of Potato Canyon and Canyon No. 8, at locality EE, a diamond-drill hole was bored 744 feet deep. (See Pl. XVI.) The Potato Canyon coal bed, which is 5 feet thick and which has a 2-inch parting in the middle of it, was penetrated. Although several other thin beds of coal below the thick bed near the surface were penetrated, as shown in the record, none of them is sufficiently thick to be of any great value. This fact, taken in connection with certain disturbances of the beds which were observed in the north wall of the canyon, suggests that the thick bed may be the Tinpan instead of the Potato Canyon coal, and that the correlation of the beds as shown on the map (Pl. I) may be in error. Conflicting evidence in upper Potato Canyon renders the identity of the beds uncertain. A massive sandstone, which is 66 feet thick, was encountered at a depth of 665 feet. At the time the hole was bored this was supposed to be the Trinidad sandstone, and the two beds of coal, each a foot or less in thickness, which occur a few feet above it, were supposed to represent the Raton coal bed. Comparison of the record with others on Plate XVI shows that this supposition may be incorrect and that the drill did not reach the Trinidad sandstone.

A prospect opening was made in 1893 some distance southwest of locality 418 but not located on the map (Pl. I). This coal is described as probably the Potato Canyon bed, although it is 107 feet lower than this bed, as described in the canyon farther west. The strata have been somewhat disturbed here by faulting and warping, which may explain the difference in altitude of the prospects. The bed opened here is reported as follows:

Section of coal bed west of locality 418, in Coal Canyon.

	Ft.	in.
Shale.		
Coal	1	3
Shale		4
Coal	1	9
Shale		2
Coal	1	3
Shale		1
Coal		6
Shale		½
Coal		6½
Shale		7
Coal	1	4
Shale.		
Total thickness of bed	7	10
Coal	6	7½

The character of the bed farther east is indicated by the sections on Plate XIX. The several benches of coal of this bed differ considerably in thickness in this region, as indicated by sections 419 to 426, inclusive, but the character of the bed as a whole is fairly constant in the north wall of Potato Canyon.

In the south wall of Canadian River canyon this bed has been opened at localities 427 to 430, inclusive, and found to contain more shale than it has in Potato Canyon. However, the partings diminish somewhat in thickness toward the west. Two of the prospect openings made in the south wall of Canadian River canyon in 1893, which are not located on the map and the sections at which are not platted, add something to the information already given of the Potato Canyon bed. In the gulch west of locality 428 the following details of the coal bed were obtained:

Section of coal bed in gulch west of locality 429, in Canadian River canyon.

	Ft.	in.
Shale		10
Shale		5
Coal	1	2
Shale		4
Coal	3	
Shale		11
Coal	1	4
Shale.		
Total thickness of bed	8	
Coal	6	4

Another prospect in the gulch near locality 430 is reported as follows:

Section of coal bed near locality 430, in Canadian River canyon.

	Ft.	in.
Shale.		
Coal	1	4
Shale		3
Coal	1	4
Shale		2
Coal		5
Shale.		
Total thickness of bed	3	6
Coal	3	1

On the ridge south of locality 428, at an altitude of 7,490 feet, a thick bed of coal was found above the Potato Canyon bed, but the lower part of it was not exposed. It was measured both north and south of the crest with the results given below. Surface indications show that this bed is prominent for a mile or more west of this locality.

Section of coal bed above the Potato Canyon coal on ridge south of locality 429.

	Locality north of crest of ridge.	Locality south of crest of ridge.
	Ft. in.	*Ft. in.*
Shale.		
Coal	1 4	6
Shale	1	2
Coal	3	6
Shale	2	5
Coal	6	8
Shale	2	3+
Coal	1 4+	(?)
Total thickness of bed	3 10+	2 6+
Coal	3 5+	1 8+

Little prospecting has been done on the Potato Canyon bed in the north wall of Canadian River canyon. The westernmost exposure north of the river of a coal that may be the Potato Canyon coal was found both north and south of the ridge at locality 431, at an altitude of 7,295 feet. This altitude is higher than the Potato Canyon coal should be at this locality, on the assumption of regularity of dip, and this coal may represent some other bed. The character of the bed differs somewhat on opposite sides of the spur at this locality, as shown in the sections platted in Plate XIX under 431.

In Canyon No. 5 coal that seems to be a bed about 100 feet higher than that of the last locality described was found in the bed of the East Fork at locality 431. Its character suggests that it may be the thick shaly bed above the Potato Canyon coal. This bed was measured at the outcrop in Canyon No. 5 as follows:

Section of coal bed in Canyon No. 5, west of locality 431.

	Ft.	in.
Sandstone.		
Coal	1	2
Shale	3	6
Coal		2
Shale		6
Coal		6
Shale	1	10
Coal		2
Shale		4
Coal		3
Bone		½
Coal		6
Shale.		
Total thickness of bed	8	11½
Coal	2	9

Half a mile still farther west, at the point marked 7583, on the spur separating Canyon No. 5 from Bruggerman Canyon, a still higher bed of coal 2 feet 3 inches thick, with shale above and below it, was found.

Three beds of coal apparently thinner than the one found at locality 431 outcrop in the slope below this locality, but they were not well exposed and nothing was learned of their character.

About 3,100 feet east of the last locality described, in the west side of the gulch, at locality 432, a coal bed, which is probably the Potato Canyon coal, crops out about 170 feet above the bed of the tream at an altitude of 7,241 feet. Another thick bed of coal crops out 122 feet higher. These beds are both disturbed by slide rock, and no measurements of them were obtained. A still higher coal, 2 feet 11 inches thick, was found at an altitude of a little more than 7,500 feet and four thin beds still higher.

On the spur 1,000 feet east of locality 432 the Potato Canyon coal crops out at an altitude of 7,241 feet, and the next higher thick bed previously described outcrops 133 feet higher. Both beds are obscured by slide rock, and no measurements were obtained. However, a good measurement was obtained of the Potato Canyon bed at locality 433, where it outcrops at an altitude of 7,261 feet, or about 250 feet above the bed of the canyon. The details of the bed at this locality as reported, are platted as section 433 in Plate XIX.

In Jones Canyon the Potato Canyon coal was opened in several places in 1893, but the openings have long since been obliterated and can now be located only approximately. Little was learned of the coal in the west wall of this canyon. The westernmost point at which a coal bed that may be the Potato Canyon Coal was observed is in the east wall of the canyon, half a mile below the mouth of Meatblock Canyon, at locality 434. An entry was driven in on this bed several years ago and some coal mined there. A sheet of intrusive igneous rock lies above the coal bed and was found within the mine resting on the coal as indicated in the following section.

Section of coal bed at locality 434, in abandoned mine in Jones Canyon.

	Ft.	in.
Coal intruded by igneous rock	1	2
Coal	3	6
Shale		1
Coal		6
Shale.		
Total thickness of bed	5	3
Coal	4	

In the side canyon which enters Jones Canyon east of the old mine igneous rock has intruded the coal bed, changing some of the coal to an impure graphite. A section was measured here as follows:

Section of coal beds in side canyon east of locality 434, in Jones Canyon.

	Ft.	in.
Shale.		
Coal		10
Shale		½
Graphitized coal	1	3
Igneous rock	3	
Shale		4
Graphitized coal	1	2
Shale.		
	6	7½

In Taber Morey Canyon, about 1 mile west of Jones Canyon, 2 feet 4 inches of coal was found, but its relation to other rocks was not determined, and a bed of coal consisting of two benches, the lower bench containing 2 feet 1 inch of clean coal, was found at about the same altitude 1½ miles north of the old mine in Jones Canyon. The upper bench, 4 feet above the lower one, was not measured because of surface slumping.

Farther downstream, in Jones Canyon, a coal which may be the Potato Canyon coal bed was observed in the east wall of Jones Canyon, at locality 435, at an altitude of 7,251 feet, or 100 feet above the bed of the canyon, where it is 2 feet 6 inches thick. The bed is disturbed by slide rock and the full thickness was not exposed. About 500 feet east of this exposure the same coal bed crops out at an altitude of 7,279 feet, where the reported measurements used in platting section 436 were made. In the west wall of Hobbs Canyon the Potato Canyon coal crops out at an altitude of 7,290 feet, where section 437 was measured. Farther north, at the fork of the canyon, locality 438, and also in the east wall of this fork, this coal is exposed. At an old prospect opening in the east wall section 439 was measured.

Several openings were made farther south and east. The Potato Canyon coal was opened in the spur east of Hobbs Canyon, at an altitude of 7,320 feet, at locality 440; in Horse Canyon, at an altitude of 7,280 feet, at locality 441, and in the bed of the canyon at an altitude of 7,347 feet, at locality 442, where the following section was measured:

Section of Potato Canyon coal bed at locality 442, in Horse Canyon.

	Ft.	in.
Shale.		
Coal		5½
Shale		2½
Coal		5½
Shale		1
Coal	1	1
Shale		4
Coal		8
Shale		1

	Ft.	in.
Coal	1	
Shale		5½
Coal		1
Shale		3
Coal		9½
Shale		1
Coal		6
Shale		10
Coal	1	3
Shale.		
Total thickness of bed	8	7½
Coal	6	3½

The same coal bed was found at localities 443 and 444.

In the spur east of the mouth of Horse Canyon, near locality 444, a coal bed occurs at an altitude of 7,450 feet, or 118 feet above the Potato Canyon coal. This is the same bed as the higher thick coal found south of Canadian River canyon. No details of it were obtained here. Farther southeast, near locality 445, the Potato Canyon coal bed has a maximum thickness of 7 feet 2 inches, but no farther details of it were obtained. The measurements made at this locality are shown in Plate XIX. In the spur north of this locality the higher thick bed of coal was observed at an altitude of 7,432 feet, or 116 feet above the Potato Canyon coal, but the exposure was too poor for detailed measurement. At another exposure in Rice Canyon, near locality 445, a coal bed, which may be the Potato Canyon coal, is only partly exposed. The higher bed was measured at this locality as follows:

Section of coal bed near locality 445, in Rice Canyon.

	Ft.	in.
Shale.		
Coal		3+
Shale	1	
Coal		6
Shale	2	
Coal		6
Shale	1	
Coal	1	
Shale	2	8
Coal		4
Shale.		
Total thickness of bed	9	3+
Coal	2	7+

This bed is well exposed at its outcrop in the bottom of Rice Canyon and was there measured as follows:

Section of coal bed at locality 446, in Rice Canyon.

	Ft.	in.
Shale.		
Coal		2½
Shale		4
Coal, shaly		6
Shale		4
Coal		8
Shale		2½
Coal		6½
Shale		3
Coal		10
Shale		½
Coal	3	½
Shale.		
Total thickness of bed	6	11½
Coal	5	9

Between Rice and Rombo canyons a sandstone forms a broad bench at an altitude between 7,350 and 7,400 feet. The lowest thick bed of coal of this region lies under this sandstone at an altitude which suggests that it might be either one of the thick beds that have been prospected in the south wall of Canadian River canyon half a mile to the southwest. This bed has been described locally as the Potato Canyon bed on the assumption that it could be traced continuously in the sides of Jones and Canadian River canyons and connected with the higher bed in Potato Canyon. On the other hand, if the sections of the Potato Canyon bed just described from Jones Canyon be examined critically they appear to correspond as nearly with those of the bed below the Potato Canyon coal as with the sections of Potato Canyon coal bed. These considerations, together with the fact that the coal below the shelf-making sandstone between Rice and Rombo canyons is the lowest thick bed of the region, indicate that this bed should be correlated with the Tinpan coal. If this correlation is correct the bed north of Canadian River, formerly supposed to be the Potato Canyon bed, is really the Tinpan coal, and the bed just described as occurring 116 feet above this bed north of Canadian River is really the upper thick bed of Potato Canyon or the true Potato Canyon coal. Much detailed work must be done before the beds of the upper group of coals can be definitely correlated from place to place.

TINPAN COAL BED.

The information regarding this bed in the district between Potato and Rombo canyons is derived mainly from a map furnished by the coal company for use in this report. On this map are located the prospects, and the sections of the bed measured in the openings are

platted on the map (Pl. I). Most of these openings could be identified on the ground at the time of the writer's investigation, but in few of them could details of the bed be obtained and therefore the measured sections as reported by the engineers are shown in Plate XXI.

Four openings were made in this bed in the gulch west of Deer Canyon. At locality 447 the bed is 5 feet 2 inches thick and consists of five benches of coal separated by partings of shale. The other three prospects indicate much the same character of bed as that shown in section 448, which was measured in the south side of the main canyon.

In the second gulch west of Deer Canyon three openings were made. Near the head of the gulch, at locality 449, the bed is somewhat thicker than it is at the localities just described, and in the bottom of Potato Canyon, at locality 450, it is 7 feet 5 inches thick.

In the north wall of Potato Canyon this bed continues with practically the same thickness and character to locality 451, and then diminishes in thickness as far as locality 452, although it still retains the same number of benches of coal, but in a spur between Potato Canyon and Canadian River canyon the thickness and character change as described below. At locality 454 there are six benches of coal. The upper five benches seem to represent the bed as opened farther west, and the lower bench is either a local development here or was not exposed in the prospects farther west. This lower bench is recognizable in the section 455 (Pl. XXI), but farther west, in the south wall of Canadian River canyon, its identity is uncertain. The bed is composed of a number of lenses of coal, and it is probable that no one of them is continuous for any considerable distance. No data concerning this coal bed were obtained in Canadian River canyon west of locality 459 nor in the north wall of this canyon, unless the coal there described as possibly the Potato Canyon bed is this bed, as has been suggested.

In the west wall of Jones Canyon this bed is 5 feet 9 inches thick at locality 460 and consists of four benches aggregating a thickness of 4 feet 7 inches of coal. Farther north in Hobbs Canyon, at locality 461, the shale partings are thinner. This bed thickens considerably to the east and the number of benches of coal in it increases. At locality 462 it is 8 feet 5 inches thick and has seven benches of coal, but it diminishes in thickness to the south and east, as shown in section 463 (Pl. XXI).

The lowest coal bed of any considerable thickness east of Rice Canyon was opened at locality 464, and the section there is given on Plate XIX. This coal seems to be fairly constant in character east and north of this locality as far at least as Rombo Canyon but is crushed in many places along the outcrop, owing probably to the

settling of the heavy sandstone overlying it. At locality 465 a prospect was opened in 1893, when this bed was described as the Potato Canyon coal. The following measurements are reported from this opening:

Section of coal bed at locality 465, east of Rice Canyon.

	Ft.	in.
Sandstone.		
Coal, shaly at top	1	6
Bone		2
Coal	1	1
Shale		1
Coal		9
Shale		2
Coal		3
Shale		3½
Coal	1	1
Shale.		
Total thickness of bed	5	4½
Coal	4	6

Another prospect opening was later made at locality 466 and the bed measured as shown in Plate XIX.

Farther north, at locality 467, this bed of coal was opened and measured, with the results indicated in Plate XIX. The next higher thick coal bed outcrops also at this locality, but no details of the bed were obtained nor were any details of it found in this canyon farther east. The lower bed was measured in openings at localities 468 to 471, inclusive, and the sections are given in Plate XIX. In the east fork of Rombo Canyon, half a mile north of locality 469, a thick coal bed, which is doubtless the same as the highest bed in Tinpan Canyon that has been described, was found at an altitude of 7,550 feet as indicated by aneroid barometer. It was measured here as follows:

Section of coal bed near locality 469, in east fork of Rombo Canyon.

	Ft.	in.
Shale.		
Coal	4	6
Shale	3	8
Coal	2	7
Shale.		
Total thickness of bed	10	9
Coal	7	1

The coal beds of the upper group underlie a large area east of Rombo Canyon, but their outcrop lies west of the district prospected by the drill between Canadian River and Dillon canyons, and hence they do not appear in the drill sections. Their presence in many places in the highland between Rombo and Dutchman canyons is

shown by surface indications of coal, but they have not been systematically prospected, and little is known of their character. In Dutchman Canyon two beds have been opened. The lower one has been traced along the outcrop from the south fork of Dutchman Canyon northward into Dillon and Tinpan canyons, where it is known as the Tinpan coal. There it has been thoroughly prospected and a mine opened in it at Brilliant.

UPPER CANADIAN RIVER AND LONG CANYONS.

The coal beds that crop out in Crow Canyon and its tributaries seem to extend through the highlands between Crow and Canadian River canyons and to crop out in Canadian River canyon, but few openings have been made on these beds west of the mouth of Jones Canyon.

In an exposure of rocks 123 feet thick at locality 472, east of the mouth of Corduroy Canyon, 2½ miles from the west border of the Brilliant quadrangle, eight coal beds 5 feet or more apart were found, but the thickest bed of coal observed is only 2 feet 4 inches thick. The section is as follows:

Section of coal-bearing rocks at locality 472, in north wall of Canadian River canyon east of mouth of Corduroy Canyon.

	Ft.	in.
Sandstone and shale	20	
Coal, shaly		6
Shale	10	
Coal	2	4
Shale, sandy	17	
Coal		2
Shale	8	
Coal		7
Shale, sandy	6	
Coal		4
Shale	5	
Coal		10
Shale	2	
Sandstone	8	
Shale, sandy	5	
Coal		7
Shale		3
Coal	2	
Shale	18	
Coal		2
Shale	3	
Coal		3
Sandstone and shale	20	
Coal		7
Shale		10
Coal		4
Shale		2
Coal		2
Shale.		
	132	1

Just west of the mouth of Canyon No. 9 a bed of coal was measured in the south wall of Canadian River canyon as follows:

Section of coal bed at localtiy 473, in Canadian River canyon just west of Canyon No. 9.

	Ft.	in.
Shale.		
Coal	1	3
Shale		10
Coal		5
Shale.		
Total thickness of bed	2	6
Coal	1	8

In the bed of Canyon No. 9, at locality 474, at a horizon 50 feet above the bed just described, 2 feet 10 inches of clean coal with shale above and below it was found.

Farther west, at the mouth of McCuen Canyon, a bed of coal exposed at the side of the road was measured as follows:

Section of coal bed at locality 475, at mouth of McCuen Canyon.

	Ft.	in.
Shale.		
Coal		2
Shale		9
Coal		6
Shale	2	
Coal		9
Shale.		
Total thickness of bed	4	2
Coal	1	5

About half a mile farther west a coal bed is exposed in the north wall of the main canyon and was measured as follows:

Section of coal bed at locality 476, near mouth of T X Canyon.

	Ft.	in.
Shale.		
Coal		3
Shale		2
Coal	1	2
Shale		3
Coal		10
Shale.		
Total thickness of bed	2	8
Coal	2	3

In the south wall of the canyon, 500 feet farther west, the same bed gave the following measurements:

Section of coal bed at locality 477, west of mouth of T X Canyon.

	Ft.	in.
Shale.		
Coal		2
Shale		3
Coal	2	6
Shale.		
Total thickness of bed	2	11
Coal	2	8

Near the mouth of T B L Canyon coal was exposed as follows:

Section of coal bed at locality 478, near mouth of T B L Canyon.

	Ft.	in.
Shale.		
Coal		6
Shale		2
Coal	1	5
Shale.		
Total thickness of bed	2	1
Coal	1	11

In the wall of the main canyon a few hundred feet north of the mouth of T B L Canyon an old mine opening was found on a bed 100 feet or more above the stream. This mine furnished coal for local use many years ago, and the coal bed in the mine is reported to be 3 or 4 feet thick. The opening was not accessible when the writer examined it, but the coal bed as measured at the outcrop near the old mine is as follows:

Section of coal bed at locality 479, a few hundred feet north of mouth of T B L Canyon.

	Ft.	in.
Shale.		
Coal		7
Shale		4
Coal	1	5
Shale.		
Total thickness of bed	2	4
Coal	2	

In the south wall of the canyon a quarter of a mile west of the old mine, at locality 480, a coal bed that is apparently the same as that at which the mine was opened was measured at the outcrop as follows:

Section of coal bed at locality 480.

	Ft.	in.
Shale.		
Coal		8
Shale		5
Coal	1	8
Shale.		
Total thickness of bed	4	9
Coal	2	4

These coal beds may be stratigraphically above those prospected farther downstream, in Canadian River canyon, but without extensive prospecting the individual beds could not be traced and their relation to those previously described determined. The surface exposures that were found do not indicate valuable beds, so that it is not known whether any of the coal beds that crop out in upper Canadian River canyon are of economic value under present conditions.

In Long Canyon, in the northwest corner of the Brilliant quadrangle, several thin beds of coal were found that may be the same as those that crop out in the upper part of Canadian River canyon, but none was found in Long Canyon that is likely to be of economic value under present conditions. The relation of the coal beds in Long Canyon to those farther east in the vicinity of Brilliant is not known.

AREA BETWEEN ROMBO CANYON AND DUTCHMAN CANYON.

GENERAL FEATURES.

The outcrop of the coal beds in Rombo Canyon is separated from the outcrop of beds in Dutchman Canyon by little more than a mile, and the coal probably extends uninterruptedly through the intervening ridge separating the two canyons.

In the south fork of Dutchman Canyon a thickness of 4 feet of coal was found in this bed, but the bed is not fully exposed. A prospect was made at locality 481, where the outcrop crosses the stream, and two others in the north wall of the canyon at localities 482 and 483. Several openings were made on the same bed farther north and west at localities 484 to 490, inclusive, in the south wall of Dillon Canyon. The character of the coal bed is indicated in the sections in Plate XIX.

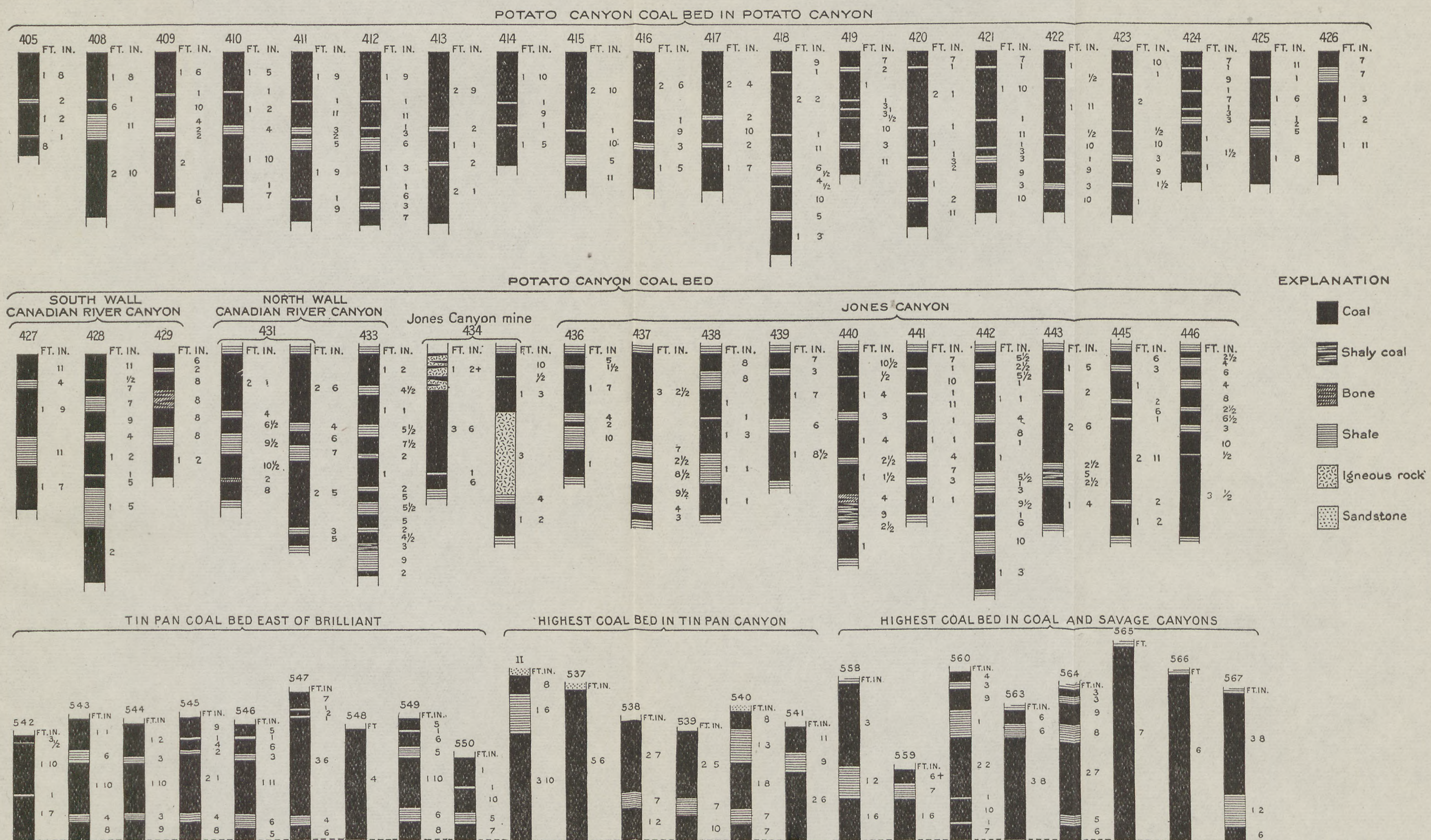
This bed still farther to the west and north will be described in connection with the Brilliant mine.

There are several thin coal beds above the Tinpan coal, that may be of economic value in some places. One bed 141 feet above this coal was opened in Dutchman Canyon at localities 533, 534, and 535 and was measured as follows:

Sections of coal bed at localities in Dutchman Canyon.

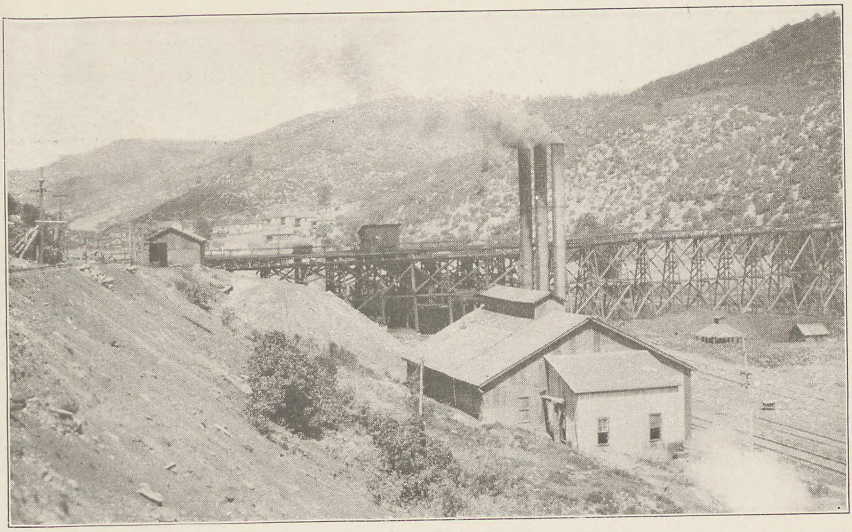
	Locality 533.		Locality 534.		Locality 535.	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal		5		6	1	8
Shale	1	4		6	(?)	
Coal	1	8	1	8	2	11
Total thickness of bed	3	5	2	8	4	7+
Coal	2	1	2	2	4	7

In Tinpan Canyon near the Brilliant mine, at practically the same horizon as the upper Dutchman Canyon bed—that is, 153 feet above the Tinpan coal—a bed was found that has much carbonaceous shale but little coal, and another one between these two beds, or 63 feet above the Tinpan coal, makes considerable showing at the outcrop but is mostly black shale. These higher beds near Brilliant will be described later in this bulletin.

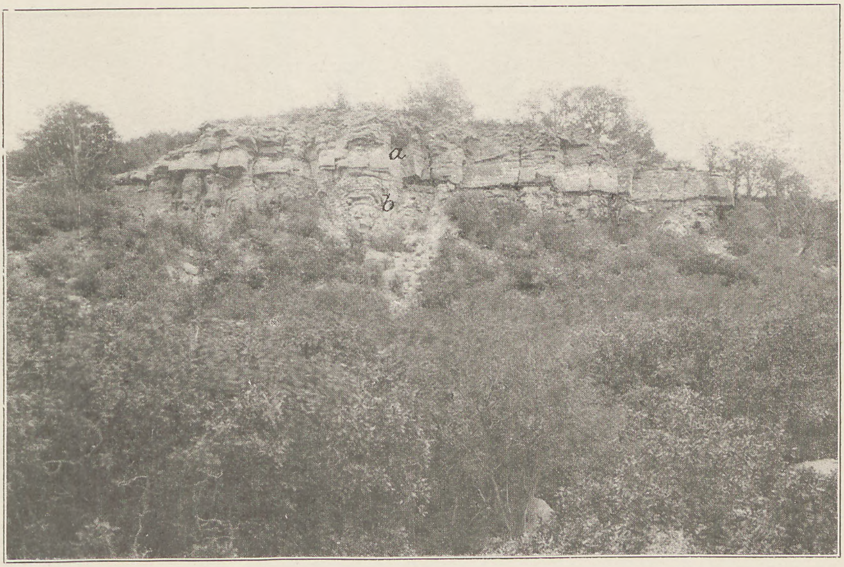


SECTIONS OF COAL BEDS BETWEEN POTATO CANYON AND ROMBO CANYON.

Numbers over the sections correspond to locality numbers on Plate I.



A. COAL MINE AT BRILLIANT.



B. BLUFF SOUTH OF YANKEE.

The Raton formation (*a*) lies unconformably on the Trinidad sandstone (*b*). Farther west the Vermejo beds lie between these two formations.

SECTIONS OF COAL BEDS BETWEEN POTATO, RED RIVER, JONES, AND ROMBO CANYONS, N. MEX.

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

BRILLIANT MINE.

Development.—A mine was started on the Tinpan coal bed at Brilliant, in Dillon Canyon, and the main entry was driven southward through the spur to Tinpan Canyon. (See Pl. XX, *A*.) A tramway was later built across Tinpan Canyon to an entry in the same bed in the south wall of the canyon. The altitude of the bed is about 7,200 feet. Slight variations in altitude are caused by slight faulting and warping of the strata. A drill hole in Tinpan Canyon at locality FF, a little above the coal bed, reached what is believed to be the Trinidad sandstone at a depth of 704 feet. (See section FF, Pl. XVI, p. 152.) This record proves that although the Tinpan bed is the lowest thick coal of the upper group in this district at least three other coal beds of this group underlie it and may be thick in some places. Several other drill holes have been bored in the vicinity of Brilliant, and their records show the relation of the Tinpan coal to neighboring beds. The records previously described have been platted to the same scale and arranged in Plate XVI in such a way as to show the stratigraphic relations of the coal beds.

Before the mine was opened several prospect openings were made on the outcrop of the coal bed in Tinpan and Dillon canyons. The more important of these are located on the accompanying map by locality numbers 491 to 507, inclusive. The character of the bed, as indicated by the measurements reported by the engineers who opened it, is shown in the sections in Plate XXI. In all these sections a thick bench of coal was found which seems to be persistent over the prospected area. Sections 509 to 533 have been platted in such a way as to show this continuity. In some of the sections thinner benches appear above the main bench and others below it. These thin benches both above and below the main coal may be present at all the localities prospected, but at some places the openings may not have extended far enough to expose them. However, there is nothing in the records as reported to indicate their presence except where the sections show them.

Roof of mine.—The main coal is overlain by shale, above which is an upper bench of coal. The two are ordinarily left to form the roof. The shale is not jointed so far as was discovered, and does not fall readily when the underlying coal is removed. Its lower surface is smooth, and it parts readily from the coal. The shale contains many impressions of plants, especially palms. Few rolls or horsebacks have been encountered in the mine between Tinpan and Dillon canyons, but south of Tinpan Canyon many rolls and small faults were encountered and in some places the absence of coal suggests that channels have been eroded in the coal bed and later filled with mud.

The coal.—The bed contains a lustrous black bituminous coking coal, more or less banded, owing to layers of lustrous coal alternating with layers of dull coal. It is much softer than the older coal of the Raton bed. A sample was collected for analysis by the writer on August 30, 1913, at a mining face in the extension of the mine south of Tinpan Canyon, in a room off the main or No. 5 entry, at locality 512 near a fault line. Here the bed was measured as follows:

Section of coal bed at locality 512, in Brilliant mine, south of Tinpan Canyon.

	Ft.	in.
Shale.		
Coal (sampled)		6
Shale		2
Coal (sampled)		9
Shale		8
Coal (sampled)	1	9
Bone		½
Coal (sampled)	1	2
Shale		2
Coal (sampled)		8
Shale.		
Thickness of bed	5	10½
Thickness of coal sampled	4	10

The chemical character of the coal is given in analysis 17703 in the table on page 244.

Two samples were taken for analysis in the main mine between Tinpan and Dillon canyons by J. S. Burrows and J. W. Groves on May 9, 1906. Sample 3228 was taken 475 feet southwest of the drift mouth in the south wall of Dillon Canyon, and sample 3229 was taken 800 feet southeast of the drift mouth in room 11 off main entry No. 3. The character of the bed at these localities is indicated by the following sections:

Sections of coal bed in Brilliant mine.

	Laboratory No. 3228.		Laboratory No. 3229.	
	Ft.	*in.*	*Ft.*	*in.*
Shale and bony coal.				
Coal (sampled)		9	1	10
Bone	1	4		
Sandstone				2½
Coal (sampled)	1	6	2	2
Sandstone (sampled)		¾		
Coal (sampled)	2			
Shale.				
Thickness of bed	5	7¾	4	2½
Thickness of coal sampled	4	3	4	

Although the Brilliant coal is a coking coal it differs greatly in this respect from the older coal in the Raton bed. Coke from the Brilliant coal is weak and inferior in some ways to that made from

the Raton coal. However, when the two coals are mixed a satisfactory grade of coke is obtained.

The coal bed differs considerably in character from place to place, as judged from the sections of it measured in the mine. However, these sections represent only the portions of the bed removed in mining and do not indicate the benches of coal that may occur below or above the main bench. They are valuable in showing the character of the minable portions but should not be interpreted as showing any material change in the character of the bed from that indicated by the sections of Plate XXI, measured in the prospect openings at the outcrop. The sections are selected to show as wide a range as possible in the mine. They were measured at localities 509 to 533, inclusive (Pl. I).

In the mine south of Tinpan Canyon the principal part of the coal now mined occurs in two benches separated by a half-inch parting of sandy shale, although at some of the localities where sections were measured other benches both above and below the main coal are exposed. The bed has essentially the same character where it was penetrated by the drill at locality FF, near locality 514. (See Pl. XXI.) In most places in the mine between Tinpan and Dillon canyons the thin shale parting can be recognized in the middle of the main body of coal, but in only a few places do the recorded mine measurements take cognizance of it.

In many places one of the benches of coal above the main bed has been removed in mining, as indicated by the sections in Plate XXI, but in other places this bench is left in the roof. The bench below the main coal has not been removed.

In the main part of the mine south of Brilliant, 1,000 feet from the mouth, the writer measured a section near locality 522, which supplements the measurement of the section at that locality (see Pl. XXI), and also shows that the main coal is separated here as elsewhere in this mine into two benches by the thin band of shale. The section follows:

Section of coal bed near locality 522, in the Brilliant mine.

	Ft.	in.
Shale.		
Coal	1	6
Shale	1	1
Coal	1	6
Shale		½
Coal	2	1
Shale.		
Total thickness of bed	6	2½
Coal	5	1

About 50 feet north of locality 522 the thin beds of coal both above and below the main coal are exposed in a cut made for the main entry, in crossing a fault that has a downthrow of 12 feet on the north. Although this is a normal fault, the coal bed is warped as if it were a thrust fault. In this respect it is similar to the fault in the Willow mine described on page 57 and shown in figure 7. A section was measured here as follows:

Section of coal bed near locality 522, at fault in the Brilliant mine.

	Ft.	in.
Shale.		
Coal		10
Shale		9
Bone		6
Coal	1	4
Shale		½
Coal (lowest bench mined)	2	3
Shale		9
Coal		10
Shale	1	4
Coal		6
Shale		4
Sandstone.		
Total thickness of bed	9	5½
Coal	5	9

About 500 feet south of the fault, in the main entry, the writer measured a section near locality 520. This supplements the engineer's measurements platted as section 520 and shows the occurrence of the thin shale in the main coal. This section is as follows:

Section of coal bed near locality 520, in the Brilliant mine.

	Ft.	in.
Shale	5±	
Coal		10
Shale		2
Coal		9
Shale	1	
Coal	1	8
Shale		1
Coal	1	10
Shale.		
Total thickness of bed	11	4±
Coal	5	1

In room 3 off the fifth west entry, about 200 feet west of locality 520, measurements were made as follows:

Section of coal bed in room 3, off fifth west entry, Brilliant mine.

	Ft.	in.
Shale.		
Coal	1	10
Shale		11
Coal	1	9
Shale		½
Coal	2	
Shale.		
Total thickness of bed	6	6½
Coal	5	7

The shale parting below the highest bench, where this bench has been removed in mining, differs considerably from place to place both in thickness and character. In the southern part of the mine north of Tinpan Canyon it is about a foot thick, but farther north it is represented in some places by bony coal. West of locality 517 it becomes thinner and the main body of coal becomes thicker. At the end of the entry a thickness of 5 feet 8 inches of coal was mined at locality 516. The bed extends westward with its character little changed as far as the diamond-drill hole at locality GG. The record of this drill hole shows that the main bench is here 3 feet 10 inches thick and that a higher bench 8 inches thick is separated from the main bench by 11 inches of shale. But at locality HH the Tinpan bed was found to be only 2 feet thick.

The measurements of the coal bed that were made in mine No. 2, northeast of Dillon Canyon, have been platted as sections 528 and 529 on Plate XXI. The highest bench of coal described in the main mine south of Dillon Canyon here increases in thickness, but the shale and bony coal intervening between the main bench and the highest bench also increases as the thickness of the main bench decreases. For these reasons this part of the mine had been abandoned some time before the writer made his first investigation. However, in 1919, when he again visited this region, mining operations had been renewed. The main entry of mine No. 2 had been extended east of locality 530 and other entries started. In these easternmost workings the lower bench is removed, leaving the upper bench to be taken down when the pillars are finally drawn.

The character of the coal bed in the prospect openings north of Dillon Canyon indicates that the mine on this side of the canyon was started in an unfavorable place for profitable operation. In it two thick benches of coal were encountered, separated by shale, bony coal, and sandstone so thick that operations were seriously interfered with. (See sections 528, 529, and 530, Pl. XXI.) The later developments, however, show that east of the original workings more favorable conditions prevail.

Joints are well developed in all parts of the Brilliant mine, the cleat faces being 2 to 5 inches apart. They run parallel to the dip of the bed in a direction about N. 75° W. The cross entries are driven on the butts and the rooms on the faces.

Coal from the Brilliant mine produces a good coke but one that is lighter and more "fingery" than that made from the Raton coal. Practice has shown that by mixing this coal with the Raton coal a very satisfactory coke is produced. The coal from the Brilliant mine weathers somewhat rapidly when exposed to the atmosphere and breaks up badly when shipped. Coal that had been exposed three weeks was badly checked and the lumps fell in pieces when disturbed, but no tendency to spontaneous burning has been noted except in the damp refuse from the washer. It breaks easily and is screened at the tipple into lump (25 per cent), nut (30 per cent), and "slack" (45 per cent).

Two samples of coal, No. 4A and No. 4B, were taken from this mine for testing by J. S. Burrows and J. W. Groves on May 9, 1906. The tests were made at the U. S. Geological Survey fuel-testing plant at St. Louis, and the results are as follows:[13]

New Mexico No. 4A consisted of run-of-mine coal and was used in making steaming tests 397 (raw) and 398 (washed), producer-gas test 122, and washing test 174. New Mexico No. 4B consisted of slack coal through a 1¼-inch perforated screen, and was used in making steaming test 395, washing test 170, coking tests 150 (raw) and 151 (washed), and cupola test 119. Mixed with New Mexico No. 3B and No. 5 (equal portions, washed), No. 4B was also used in coking test 152 and cupola tests 98 and 130.

Two mine samples were taken for chemical analysis. Sample 3228 was taken 475 feet southwest of the drift mouth, where the coal measured 5 feet 8 inches in thickness. Sample 3229 was taken 800 feet south of the drift mouth, where the coal measured 4 feet 3 inches in thickness.

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[13] Holmes, J. A., and others, Report of the United States fuel-testing plant at St. Louis, Mo.; U. S. Geol. Survey Bull. 332, pp. 181-184, 1908.

The following tables show the chemical character of this coal and give the results of different tests of it:

Chemical analyses of New Mexico No. 4 coal.

	Mine samples.		Car samples.		Steaming tests.[a]		
			A.	B.	A.		B.
					397.	398.	395.
Laboratory No	3228	3229	3331	3315	....	....	....
Air-drying loss	1.00	1.30	1.40	1.70	....	....	....
Proximate:							
Moisture	2.19	2.67	2.78	3.38	2.30	3.86	3.37
Volatile matter	35.95	36.25	34.31	34.63	34.59	34.06	34.70
Fixed carbon	50.75	51.26	48.34	48.45	48.53	50.68	48.18
Ash	11.11	9.82	14.57	13.54	14.58	11.40	13.75
Sulphur	.57	.58	.61	.61	.60	.63	.62
Ultimate:							
Hydrogen	....	....	5.06	5.13	4.89	5.07	4.91
Carbon	....	....	68.51	68.67	70.54	73.07	70.90
Nitrogen	....	....	1.51	1.50	1.56	1.61	1.55
Oxygen	....	....	9.74	10.55	7.48	7.73	7.77
Ash	....	....	....	....	.61	.66	.64
Sulphur	....	....	....	....	14.92	11.86	14.23
Calorific values (as received):							
Determined: calories	7,257	....	6,830	6,914	....	....	....
Determined: B. t. u.	13,063	....	12,294	12,445	....	....	....
Calculated from ultimate analysis: calories	....	....	6,873	6,875	....	....	....
Calculated from ultimate analysis: B. t. u.	....	....	12,371	12,375	....	....	....

[a] Proximate analysis of fuel as fired; ultimate analyses of dry fuel figured from car sample.

Steaming tests of New Mexico No. 4 coal.

	A.		B.
	Test 397.	Test 398 (w.).	Test 395.
Size as shipped	run of mine.	run of mine.	slack.
Size as used:			
Over 1 inch ..... per cent	21.3	17.4	1.7
½ inch to 1 inch ..... do	23.2	21.6	17.8
¼ inch to ½ inch ..... do	18.8	25.2	27.4
Under ¼ inch ..... do	36.7	35.8	53.1
Duration of test ..... hours	10.0	10.07	10.08
Heating value of coal ..... B. t. u. per pound dry coal	12,659	13,149	12,847
Force of draft:			
Under stack damper ..... inch water	0.64	0.64	0.61
Above fire ..... do	.25	.25	.22
Furnace temperature ..... °F	2,336	2,534	2,285
Dry coal used per square foot of grate surface per hour ..... pounds	22.76	21.92	21.33
Equivalent water evaporated per square foot of water-heating surface per hour ..... pounds	3.71	3.86	3.59
Percentage of rated horsepower of boiler developed	103.9	108.1	100.6
Water apparently evaporated per pound of coal as fired ..... pounds	6.79	7.23	6.96
Water evaporated from and at 212° F.:			
Per pound of coal as fired ..... do	7.97	8.47	8.14
Per pound of dry coal ..... do	8.16	8.81	8.43
Per pound of combustible ..... do	9.84	10.17	10.10
Efficiency of boiler, including grate ..... per cent	62.25	64.70	63.37
Coal as fired:			
Per indicated horsepower hour ..... pounds	3.55	3.34	3.47
Per electrical horsepower hour ..... do	4.38	4.12	4.29
Dry coal:			
Per indicated horsepower hour ..... do	3.47	3.21	3.35
Per electrical horsepower hour ..... do	4.28	3.96	4.14

Producer-gas test of New Mexico No. 4 A (run of mine) coal.

Test 122.—Duration of test, 50 hours. Average electrical horsepower, 189.5. Average B. t. u. per cubic foot of gas, 135.3. Total coal fired, 13,110 pounds.

	Coal as fired.	Dry coal.	Combustible.
COAL CONSUMED IN PRODUCER PER HORSEPOWER HOUR (POUNDS).			
Per electrical horsepower:			
Commercially available	1.48	1.44	1.24
Developed at switchboard	1.38	1.35	1.16
Per brake horsepower:			
Commercially available	1.25	1.22	1.05
Developed at engine	1.18	1.15	.99
EQUIVALENT USED BY PRODUCER PLANT (POUNDS).			
Per electrical horsepower:			
Commercially available	1.62	1.58	1.36
Developed at switchboard	1.52	1.48	1.28
Per brake horsepower:			
Commercially available	1.38	1.34	1.16
Developed at engine	1.29	1.26	1.08

Analyses.

Coal.

Moisture	2.42
Volatile matter	34.82
Fixed carbon	49.23
Ash	13.53
Sulphur	.63

Gas by volume.

Carbon dioxide (CO_2)	10.6
Carbon monoxide (CO)	17.0
Hydrogen (H_2)	12.6
Methane (CH_4)	2.0
Nitrogen (H_2)	57.2
Ethylene (C_2H_4)	.6

Washing and coking tests of New Mexico No. 4 coal.

Washing tests.

	Test 174 (A).	Test 170 (B).
Size as shipped	run of mine.	slack.
As used	crushed to 2 inches.	slack.
Jig used	Stewart.	Stewart.
Raw coal ... pounds	20,000	24,000
Washed coal ... do	16,275	21,000
Refuse ... do	3,725	3,000

Coking tests (B).

	Test 150 (raw).	Test 151 (washed).
Size as used	finely crushed.	finely crushed.
Duration of test ... hours	49	43
Coal charged ... pounds	11,790	11,430
Coke produced ... do	7,610	6,986
Coke produced ... per cent	64.55	61.12
Breeze produced ... pounds	362	307
Breeze produced ... per cent	3.07	2.69
Total yield ... do	67.62	63.81

Remarks.—Test 150: Light gray and silvery; good heavy coke; ash high. Test 151: Light gray and silvery; good heavy coke; ash reduced by washing.

Analyses.

	Washing test 174 (A).		Washing test 170 (B).		Coking test 150 (B).		Coking test 151 (B).	
	Raw.	Washed.	Raw.	Washed.	Coal.	Coke.	Coal.	Coke.
Moisture	2.78	3.71	3.38	5.97	3.69	1.10	5.52	1.39
Volatile matter	34.31	....	34.63	....	34.62	.94	35.29	.85
Fixed carbon	48.34	....	48.45	....	47.83	78.48	49.87	83.66
Ash	14.57	11.39	13.54	9.41	13.86	19.48	9.32	14.10
Sulphur	.61	.58	.61	.65	.66	.58	.67	.60

Cupola test of coke made from New Mexico No. 4 B coal (washed).

Charge.

Cupola test No.	Coke.[a]			Fluidity strip full.	Materials.	Divisions of charge.					Total.
	Test No.	Specific gravity.	Ratio iron to coke.			1	2	3	4	5	
				Per ct.		*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
119	151	1.92	7	98.61	Coke	200	58	58	57	57	430
					Pig iron	600	413	413	412	412	2,250
					Scrap	200	138	138	137	137	750

[a] Phosphorus in coke, 0.0946 per cent.

Record of melt.

Cupola test No.	Blast pressure.		Iron running in—	Weight of iron.			Melting.				Recovered.	
	On at—	Maximum.		Poured.	Additional melted.	Total.	Time.	Rate per hour.	Ratio iron to coke.	Loss.	Iron.	Coke.
		Oz.	*Min.*	*Lbs.*	*Lbs.*	*Lbs.*	*Min.*	*Lbs.*		*Per ct.*	*Lbs.*	*Lbs.*
119	8.57 a. m.	7	6	2,210	351	2,561	31	4,957	7.30	9.23	162	79

Ladle record.

Ladle No.	Test 119.		Ladle No.	Test 119.	
	Pounds.	Time (a. m.)		Pounds.	Time (a. m.)
1	95	9.12	14	83	9.25
2	53	9.12½	15	76	9.26
3	96	9.16	16	103	9.26½
4	94	9.16½	17	81	9.27
5	28	9.17	18	88	9.28
6	88	9.19	19	106	9.28½
7	102	9.20	20	86	9.29
8	70	9.20½	21	70	9.29½
9	89	9.21	22	101	9.31
10	66	9.23	23	82	9.32
11	86	9.23½	24	65	9.32½
12	85	9.24	25	69	9.33
13	106	9.24½	26	142	9.34

The entrance to the mine is by double drift entry, timbered with props and crossbars. The room and pillar system of mining is used. The main entry No. 3 is driven on the strike and the cross entries on the dip. The mine is ventilated by an electrically driven exhaust fan. It is free from gas, and open lights are used. It is dry in most places, but one electrically driven pump has been installed. The coal is mined by undercutting, and no shooting is required, as the coal usually falls of its own weight or is easily wedged down. Hauling is done by mules and by electric motors. The electrical plant originally established at the mine was closed in 1919, and since that time power for mining operations has been obtained by long-distance transmission from Trinidad, Colo.

The tipple is a steel structure built near the mouth of the mine and provided with shaker screens that sort the coal to lump, nut, and "slack." The lump and most of the nut are used for making steam, mainly in the locomotives of the Atchison, Topeka & Santa Fe Railway. Some of the nut is used for domestic fuel, and the slack is shipped to Gardiner, where it is mixed with coal from the Raton bed and coked. Six hundred tons of coal per day were being shipped at the time of the writer's investigation in 1913, and the maximum capacity of the mine was reported to be 1,000 tons a day.

After the writer's work in this region had been completed, the engineers of the coal company extended their survey of the Tinpan bed in Dillon and Coal canyons and opened it at localities 542 to 550 inclusive. The sections measured at these localities have been placed on Plate XXI in continuity with the other sections of the Tinpan coal.

LOWER COAL BED NEAR BRILLIANT.

There is a bed of coal near Brilliant 90 feet below the Tinpan bed, which is locally of commercial value. It has been opened in both sides of Dillon Canyon southeast of Brilliant, but only one opening was accessible to the writer. This opening, known as the Wagon mine, is in the north wall of the canyon opposite locality 499. It has been run in on this bed 235 feet and coal mined for domestic use. The section measured at the end of this entry is as follows:

Section of coal bed near locality 499, in Wagon mine near Brilliant.

	Ft.	in.
Shale.		
Coal and shale		6
Coal	1	10
Sulphur		½
Coal		3
Bone		1
Coal	1	3
Shale.		
Total thickness of bed	3	11½
Coal	3	4

HIGHER COAL BEDS NEAR BRILLIANT.

Several thin beds of coal crop out near Brilliant above the Tinpan bed. The record of the drill hole at locality JJ indicates that in the 600 feet of rocks above the Tinpan bed there are sixteen beds of coal so distributed that with one exception the beds are less than 100

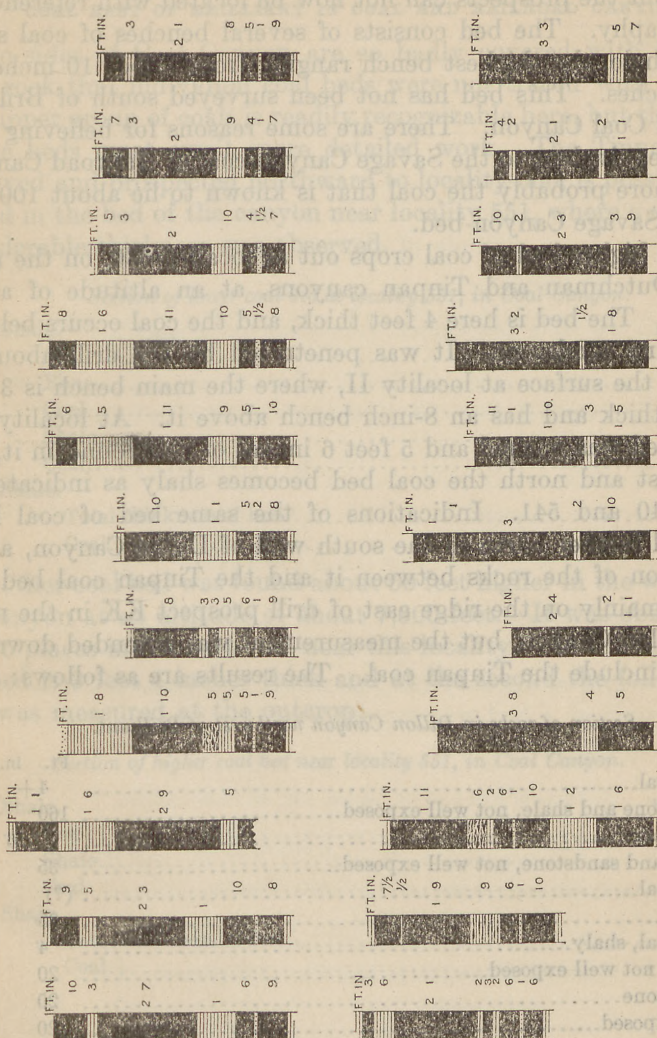

FIGURE 10.—Sections of a coal bed about 200 feet above the Tinpan coal in Dillon and Tinpan canyons, near Brilliant. The sections are in order from a point north of Brilliant at the left to a point in Coal Canyon at the right.

feet apart, but most of these beds are too thin to be of much value under present conditions. Coal crops out in many places in Dillon Canyon and its tributary canyons near Brilliant at horizons higher than that of the Tinpan bed, but only two of the higher beds are known to be of commercial value. One of these beds lies at an altitude of about 7,400 feet, or 150 to 200 feet above the Tinpan coal;

the other at an altitude of about 7,550 feet, or approximately 325 feet above the Tinpan coal.

The lower of these two beds has been prospected west of Brilliant and between Dillon and Coal canyons. The crop line, as determined by the engineers of the coal company, has been transferred to the map, but the prospects can not now be located with reference to the topography. The bed consists of several benches of coal separated by shale, the thickest bench ranging from 1 foot 10 inches to 3 feet 8 inches. This bed has not been surveyed south of Brilliant nor east of Coal Canyon. There are some reasons for believing that it may be equivalent to the Savage Canyon coal of Railroad Canyon, but it is more probably the coal that is known to lie about 100 feet below the Savage Canyon bed.

The still higher bed of coal crops out at locality 536, on the ridge between Dutchman and Tinpan canyons, at an altitude of about 7,550 feet. The bed is here 4 feet thick, and the coal occurs below a ledge-making sandstone. It was penetrated by the drill about 80 feet below the surface at locality II, where the main bench is 3 feet 10 inches thick and has an 8-inch bench above it. At locality 537 this coal bed was opened and 5 feet 6 inches of coal found in it, but farther west and north the coal bed becomes shaly as indicated in sections 540 and 541. Indications of the same bed of coal have been noted farther north in the south wall of Dillon Canyon, and a short section of the rocks between it and the Tinpan coal bed was measured mainly on the ridge east of drill prospect KK in the north wall of Dillon Canyon, but the measurement was extended down the canyon to include the Tinpan coal. The results are as follows:

Section of rocks in Dillon Canyon northwest of Brilliant.

	Ft.	in.
Coal	4+	
Sandstone and shale, not well exposed	160	
Coal		6
Shale and sandstone, not well exposed	35	
Coal	(?)	
Shale	35	
Coal, shaly	4	
Shale, not well exposed	20	
Sandstone	20	
Not exposed	20	
Coal, Tinpan bed.		
	298	6+

The barometer indicated an altitude of 7,450 feet for the highest bed in Dillon Canyon, which therefore crops out considerably above locality KK and does not appear in the drill record of this locality. The bed was found north of Brilliant in one of the side canyons at an altitude of about 7,475 feet, and it occurs farther northeast in

Coal Canyon at practically the same altitude. It was observed in the west wall of Coal Canyon and in several places in the east wall, but unlike some of the lower beds it makes little showing at the outcrop, so that few exposures were found where its character could be determined.

COAL EAST OF BRILLIANT IN COAL AND RAILROAD CANYONS.

The sides of Coal Canyon are so badly covered with brush and slide rock that individual coal beds were not traced with certainty. The upper group of coals is readily recognizable here, but the identity of the beds must await more detailed work. The Tinpan bed, as surveyed and prospected northward to locality 550, is possibly represented in the bed of the canyon near locality 551, where a coal bed of considerable thickness was observed.

Section of lower coal bed at locality 551, in Coal Canyon.

	Ft.	in.
Shale.		
Coal		6
Bone		2
Coal		11
Shale		5
Coal	1	6
Shale.		
Total thickness of bed	3	6
Coal	2	11

Another coal bed was found about 50 feet higher in the west wall of the canyon at an altitude of about 7,300 feet. It was observed also in two places in the east wall near this locality. At the first locality the bed is 3 feet 4 inches thick and at the second the following section was measured at the outcrop:

Section of higher coal bed near locality 551, in Coal Canyon.

	Ft.	in.
Shale.		
Coal	1	4
Shale		1
Coal	1	4
Shale.		
Total thickness of bed	2	9
Coal	2	8

A coal bed about 50 feet higher may represent the first thick bed above the Tinpan coal. (See last section in fig. 10.) It was measured at the outcrop as follows:

Section of coal bed 50 feet above that at locality 551, in Coal Canyon.

	Ft.	in.
Shale.		
Coal	2	8
Shale		1
Coal		2
Shale		6
Coal		6
Shale.		
Total thickness of bed	3	11
Coal	3	4

Still higher, at an altitude of about 7,500 feet, a thick bed of coal was measured as follows:

Section of coal bed in Coal Canyon, near locality 551, at altitude of 7,500 feet.

	Ft.	in.
Shale.		
Coal	1	9
Shale		2
Coal	1	
Shale		2
Coal		1
Shale		5
Coal		8
Shale.		
Total thickness of bed	4	3
Coal	3	6

Farther north, at locality 552, at nearly the same altitude as the bed last described, a bed was measured at its outcrop in three places a few rods apart, as follows:

Sections of coal beds at locality 552, in Coal Canyon.

	A		B		C	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Shale.						
Coal		6		6		5
Shale		8		5		4
Coal		9		2		4
Shale		8	1	4	1	2
Coal	1	3	1	4	1	4
Shale	1	4	1	2	1	4
Coal		2		4		2
Shale		1		4		5
Coal		4		5		6
Shale.						
Total thickness of bed	5	9	6		6	
Coal	3		2	9	2	9

This bed thickens toward the north and contains more coal, although in character it differs but little from that noted at the localities just described. It was measured at the outcrop, at locality 553, as follows:

Section of coal bed at locality 553, in Coal Canyon.

	Ft.	in.
Shale.		
Coal	1	6
Shale		6
Coal		2
Shale	1	2
Coal	2	
Shale	1	2
Coal	1	2
Shale.		
Total thickness of bed	7	8
Coal	4	10

At locality 554 the middle one of the three beds described at locality 553 contained 3 feet 6 inches of coal with shale above and below it, and the highest bed contained 3 feet 8 inches of coal with shale above it but the base not exposed; probably the full thickness of neither of these beds was exposed.

Still farther to the south, at locality 555, the middle bed is fairly well exposed and was measured at the surface, as follows:

Section of middle coal bed at locality 555, in Coal Canyon.

	Ft.	in.
Shale.		
Coal		10
Shale		5
Coal	1	1
Shale		9
Coal		11
Shale.		
Total thickness of bed	4	
Coal	2	10

In the south wall of the gulch east of locality 555 the lowest bed was found at an altitude of 7 200 feet, as measured by barometer. It was measured at the outcrop as follows:

Section of lowest coal bed at locality 555, in Coal Canyon.

	Ft.	in.
Shale.		
Coal		6
Shale		2
Coal		8
Shale		1
Coal		8
Bone	1	
Shale.		
Total thickness of bed	3	1
Coal	1	10

For a distance of nearly a mile south of the last locality described the three beds were observed in several places, but they are not well exposed. Good exposures of all three beds were found in the next gulch to the south, at locality 556. Here the lowest bed, which may possibly be the Tinpan coal, was measured at the surface as follows:

Section of lowest coal bed at locality 556, in Coal Canyon.

	Ft.	in.
Shale.		
Coal		3
Shale		1
Coal		4
Shale	3	2
Coal		5
Bone		2
Coal	1	4
Shale.		
Total thickness of bed	5	9
Coal	2	4

A good surface exposure of the middle bed was found a little north of locality 556 and in two other places a few rods apart in opposite sides of the gulch. The results of measurements in these three places are given below in order from north to south.

Section of coal bed at locality 556, in Coal Canyon.

	A		B		C	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Shale.						
Coal	2	2		2		5
Shale		1		3		1
Coal		10		9		7
Shale		2		2		1
Coal		9	1	3	1	1+
Shale.						
Total thickness of bed	4		2	7	2	3+
Coal	3	9	2	2	2	1+

Near locality 558, but at a point which can not now be definitely located, a bed was measured several years ago with reported results as follows:

Section of coal bed near locality 556, in Coal Canyon.

	Ft.	in.
Shale.		
Coal		3
Shale		6
Coal	1	2
Shale	2	
Coal	3	4
Shale.		
Total thickness of bed	7	3
Coal	4	9

The highest bed crops out here at an altitude of about 7,500 feet and an exposure of it, at locality 557, just west of the Scenic Highway, showed the measurements given below. It is possible that this section does not adequately represent the coal, for another measurement of this bed made a few hundred feet farther west, at locality 558, yielded the results also given below:

Sections of coal bed at localities 557 and 558, near Scenic Highway.

	Locality 557.	Locality 558.
	Ft. in.	*Ft. in.*
Shale.		
Coal	2 4	3
Shale	1 2	1 2
Coal	11	1 6
Shale.		
Total thickness of bed	4 5	5 8
Coal	3 3	4 6

A coal bed farther east, at locality 559, at the same horizon and doubtless the same bed, is exposed but probably only in part. The measurements there are as follows:

Section of coal bed at locality 559, east of Scenic Highway.

	Ft.	in.
Coal		6+
Shale		7
Coal	1	6
Shale.		
Total thickness of bed	2	7+
Coal	2	

No good exposure of this highest bed was found for a distance of nearly a mile northeast of the last locality described. At locality 560, however, this coal is well exposed and was measured with the results given below.

Section of coal bed at locality 560, in Railroad Canyon.

	Ft.	in.
Shale.		
Coal		4
Shale		3
Coal		9
Shale	1	
Coal	2	2
Shale		1
Coal		10
Shale		1
Coal		7
Shale.		
Total thickness of bed	6	1
Coal	4	8

The bed here is much thicker and more compact than that described at the last two localities, and its character suggests that the portion measured at those localities is in the middle part of the bed.

North of this locality the bed is not well exposed, and no measurements of it were made, although surface indications of the coal were seen in several places west of the railroad. East of the road it has been opened in several places and is there known as the Savage Canyon coal.

Few good exposures of the lower two beds of coal at locality 556 were found south of that place. Surface indications of coal, probably from the middle bed, were noted in several places, and the outcrop of a coal bed that is probably this middle one crosses the Scenic Highway east of the mouth of Coal Canyon near bench mark 7,403. A mile farther north this bed outcrops in the gulches west of Keota, 50 feet above a lower bed, but no exposures were found on either bed at which detailed measurements of the coal could be obtained without making prospect openings. Also, three beds of coal were found west of the railroad about half a mile northwest of Keota. Coal was found on the west side about a mile northwest of Keota, at an altitude of about 7,300 feet, at locality 561, where the following section was measured:

Section of coal bed at locality 561, in Railroad Canyon.

	Ft.	in.
Shale.		
Coal, shaly	1	1
Shale		4
Coal		3
Shale	2	
Coal		9
Shale		4
Coal	1	10
Total thickness of bed	6	7
Coal	3	11

A second bed 25 feet below the one just described contains 2 feet 6 inches of coal with shale above and below it. A third bed 16 feet below the second contains coal 1 foot 4 inches thick with shale above and below it. The highest bed just described at locality 561 is traceable northward to a point west of locality 567, as indicated on the map (Pl. I).

SAVAGE CANYON.

The highest of the three beds of coal described as occurring in Coal Canyon crops out east of the railroad, where years ago it was prospected. A mine was once opened on this bed in the east branch of Railroad Canyon, locally known as Savage Canyon, at locality 562, but it was not accessible at the time of the writer's investigation, and

no detailed information was obtained concerning it except that it furnished coal many years ago for the Atchison, Topeka & Santa Fe Railway. The character of the bed as reported for five of the prospect openings south of this old mine is shown in Plate XXI.

The rocks near locality 567 are faulted to some extent, but they are so poorly exposed that neither the amount nor the direction of displacement was ascertained. A coal bed 2 feet 4 inches thick is reported 70 feet below the Savage Canyon coal at this locality. Its relation to the coal beds in the opposite wall of the canyon, at locality 561, was not determined.

Coal beds occur in Railroad Canyon above the Savage Canyon bed, but the character of only one of these beds, known locally as the Tunnel coal, has been determined. In the railway cut near Lynn, just south of Raton Tunnel, this coal was measured as follows:

Section of coal bed at Lynn, at head of Railroad Canyon.

	Ft.	in.
Shale.		
Coal	1	6
Shale		3
Coal		5
Shale		1½
Coal		4
Shale.		
Total thickness of bed	2	7½
Coal	2	3

The bed differs in thickness and character from place to place. Although it is of little value near Lynn, it may thicken toward the southeast and correspond with a bed containing 2 feet 4 inches of clean coal that lies 164 feet above a coal bed 4 feet 10 inches thick, which is believed to be the Savage Canyon bed. (See Pl. XVI, No. 261.)

WOOTTON DISTRICT.

The beds just described in Railroad and Savage canyons crop out in the Wootton district, north of the divide that is penetrated by the Raton Tunnel, but only one of them is known to be of commercial value under present conditions. This bed, which is known locally as the Wootton coal, is the same as the Savage Canyon coal and the highest bed that is described as occurring in Coal Canyon, but the great number of coal beds in the upper group and their known variability in thickness renders long distance correlation of individual beds uncertain. There is a tendency to correlate the thickest bed at one locality with a correspondingly thick bed at another locality, if they are near the same horizon, whereas careful investigation may show that a thick bed at one locality is really equivalent to a thin bed at a neighboring locality.

A mine known as the Red Robin mine was opened by the Wootton Land & Fuel Co. in 1908 on a thick bed of coal in the east wall of the

canyon at Wootton, Colo., about a quarter of a mile north of the State line. The outcrop of the Wootton bed does not cross the State line, but a brief description of the coal is included here because of its bearing on the character of the Savage Canyon coal. The coal bed was measured in this mine at two points by J. W. Groves on January 20, 1908, and samples of the coal at each point were collected for analysis. The measurements of the bed are given in the following table:

Section of coal bed in Red Robin mine, at Wootton, Colo.

	A		B	
	Ft.	*in.*	*Ft.*	*in.*
Shale and bony coal.				
Coal (sampled)	1		1	
Shale		1		
Shale and coal				1¼
Coal (sampled)	1	10	2	10
Bone		2		
Shale and coal				1
Coal (sampled)	1	3		7
Shale		1		1¼
Coal (sampled)		4½		5
Shale and bony coal.				
Thickness of bed	4	9½	5	1½
Thickness of coal sampled	4	5½	4	10

A. Chemical character of sample shown by analysis 257-D (p. 245).
B. Chemical character of sample shown by analysis 258-D (p. 245).

The first section was measured in the second entry west of the main entry, 260 feet from the mine mouth, and the second section in the first entry west of the main entry, 275 feet from the mine mouth. The analysis of a third sample, representing run-of-mine coal from the Red Robin mine, is given as No. 345-D of the table of analyses (p. 245).

Several prospect openings on this bed were made at its outcrop, and it was penetrated at four drill prospects. From measurements thus obtained, the coal bed is known to be fairly constant in thickness and character throughout a considerable area and to be comparable with the coal in Savage Canyon just described.

Five drill holes, one started below the outcrop of the coal, were put down in the Wootton district about the year 1904. The deepest hole, half a mile east of the mine mouth, penetrated nine thin beds of coal, including the Wootton bed. Another hole was started 35 feet below the Wootton coal and reached a horizon considerably below the bottom of the first hole. The records of these two prospects are shown on Plate XVI for comparison with records of neighboring localities.

REGION EAST OF RATON.

GENERAL FEATURES.

Very little is known of the coal beds of the upper group in Bartlett Mesa. The slopes are covered so thickly with brush that coal can be seen at the outcrop in relatively few places, and little has been done

at opening the beds. It is therefore quite impossible to trace individual beds at the outcrop without extensive prospecting, and the relation of the beds just described west of this mesa to those developed farther east, near the town of Yankee, is known only in a general way.

The most complete record of the number of coal beds in the upper coal group is obtained from the drill holes put down near Yankee, the record of which is described on pages 147–149 and given on Plate XVI. The thickest of these beds have been opened only in the northeastern part of the Raton quadrangle. For this reason the coal beds of the upper group east of Raton will be described in order from east to west rather than in the reverse order, which has been followed for other parts of the field.

Where so many beds of coal as are shown by the drill record occur close together it would obviously be necessary to trace them carefully at the outcrop and open them at short distances in order to be certain of their continuity. The coals are so poorly exposed in the brush-covered sides of the mesas, even where they are best known, that it is quite impossible to follow the outcrop of even the thickest beds for any considerable distance. For this reason the upper group is here described as a whole, and the attempt is not made to carry single beds farther than they can be definitely identified.

The Yankee coal, or the lowest bed of commercial value in this group, which is named from a mine of the Yankee Fuel Co. that is located on this bed, can be identified for a considerable distance because it occurs above a cliff-forming sandstone and because numerous prospect openings have been made on it. A higher coal opened by this company is called the Kellog bed. It is known only at localities 568 and 569. The Reynolds bed, so called from the Reynolds mine, locality 594, north of Yankee, which was started on one of the higher beds, can be traced definitely for only a short distance. South of Yankee a coal of local value known as the Llewellyn bed has been developed to some extent at locality 576 in the side of Johnson Mesa, but it can be traced only a short distance.

Many difficulties were encountered in examining these upper coals. The rocks in which they occur consist principally of soft shale, which weathers to smooth slopes. Above the coal-bearing rocks occur the sheets of hard basalt that cap the mesas, and the débris from these sheets covers the slopes in many places. In addition to the unfavorable conditions thus produced the mesas receive relatively abundant rainfall, which causes a dense growth of vegetation. Some places contain forests of pine and spruce, but in most places the slopes are covered with underbrush, especially near the tops of the mesas. Furthermore, minor displacements of rock due to slumping have occurred in many places. These downward movements of the sur-

face rocks not only render doubtful the true place of a given bed in the section, but some of the coal is crushed and sheared to such an extent that the bed is not recognizable. Because of these conditions, vertical sections were measured wherever the rocks were well enough exposed, instead of the beds being traced along the outcrop, and the distance of the coal beds above some known stratum, such as the Trinidad sandstone or the top of the cliff-forming sandstone of the "barren series," was determined wherever possible.

On the public lands east of the Maxwell land grant the exposures of coal were located with reference to legal subdivisions wherever such location was possible. A word of caution, may be inserted for those who wish to use the accompanying map for locating plats of land by section, township, and range. These lands were subdivided many years ago, when accuracy in establishing land corners was not always enforced, and the corners on the ground do not all correspond with the location shown on the land plats. When this land net as platted is superimposed on the topographic map certain inconsistencies appear. For instance, roads that actually follow the section lines may be mapped within a section. But probably more serious than this, at least so far as the occurrence of coal is concerned, is the apparent error in the location of mining properties. Some mine openings, such as those of Yankee, near locality 595, appear to be in the wrong section. In interpreting the map it should be borne in mind that few of the land corners were located by the topographers on the ground and that the land net was superimposed on the map after the field work was completed. The land net as shown on the map gives a good general idea of the location of legal subdivisions of the land with reference to surface features but it does not show the correct relation by legal subdivisions of definitely located points, such as mine openings.

In order to get a broad comprehensive view of the eastern part of the Raton quadrangle before taking up the details of the mines, the localities at which coal has been found are described in order from east to west.

EASTERN SLOPE OF BARILLA MESA.

At locality 568, near the extreme northeast corner of the Raton quadrangle, in the north slope of Bear Canyon, a coal bed was found about 400 feet above the base of the coal-bearing rocks. It is the only bed that the writer found north of Bear Creek, although doubtless other beds crop out in the brush-covered slope. According to Orestes St. John, a coal bed was opened years ago near this locality, 340 feet above the base of the formation, but the exact locality is uncertain, and the old opening was not found. St. John reports that the following section was measured in this prospect:

Section of coal bed near locality 568, in Bear Creek canyon.

	Ft.	in.
Shale.		
Coal		1
Shale		4
Coal	1	7
Shale		¼
Coal		9
Shale		1
Coal	1	1
Shale.		
Total thickness of bed	3	11¼
Coal	3	6

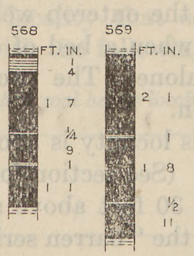

FIGURE 11.—Sections of a coal bed in Bear Canyon, in the northeastern part of the Raton quadrangle.

There are many rumors of beds of coal having been found in Bear Canyon at various times, but owing to the dense growth of underbrush in this canyon the reports were not verified. An old prospect, badly caved at the time of the writer's investigation but showing a considerable thickness of coal, was found in the south wall of Bear Canyon at locality 569. It is probably the opening described by St. John, where he measured a bed of coal as follows:

Section of coal bed probably at locality 569, on east slope of Barilla Mesa.

	Ft.	in.
Sandstone.		
Coal	2	1
Shale		1
Coal	1	8
Shale		½
Coal		11
Shale.		
Total thickness of bed	4	9½
Coal	4	8

Nothing definite can be said at present of the lateral extent of these beds, but the occurrence of similar beds in Rathbun Canyon to the south, where they have been opened, and also their occurrence in the side of the mesa north of Yankee, indicate that these beds probably extend through Barilla Mesa. Obviously, however, they do not underlie all of Horseshoe Mesa, for the cap of igneous rock and the gravel beds that underlie it occur somewhat lower than would these coal beds had they not been eroded before the gravel was deposited.

The next locality to the south at which measurements could be made on coal beds of the upper group is near locality 570, at the head of Rathbun Canyon. A thickness of about 200 feet of coal-bearing rocks is moderately well exposed here, and five of the coal beds were opened several years ago. Some of the old prospects were still accessible at the time of the writer's investigation, and measurements were made either in them or at the outcrop near them.

After these surface measurements had been made prospect openings were run in on four of the beds to points where the coal was not disturbed by surface movements. An inspection of the sections in the entries with those on the outcrop well illustrates the possibility of error in interpretation when a bed of coal is judged from its appearance at the outcrop alone. The two sets of measurements are given below for comparison.

The lowest bed near this locality is about 350 feet above the base of the coal-bearing rocks. (See section for east slope of Barilla Mesa in Pl. XVI.) It is about 30 feet above a massive sandstone which seems to be the highest in the "barren series." It is probable, therefore, that this is the Yankee coal bed. It was measured as follows:

Section of Yankee (?) coal bed at locality 570, in Rathbun Canyon.

	Surface.		In entry.	
	Ft.	*in.*	*Ft.*	*in.*
Shale.				
Coal	1	1	4	
Shale		9		3
Coal	2	10		8
Shale		8		8
Coal		6		8
Shale.				
Total thickness of bed	5	10	6	3
Coal	4	5	5	4

The second bed, which seems to be of commercial value, occurs about 85 feet above the one just described. This bed has the following aspect:

Section of coal bed at locality 570, 85 feet above Yankee (?) coal bed in Rathbun Canyon.

	Surface.		In entry.	
	Ft.	*in.*	*Ft.*	*in.*
Shale.				
Coal	2	8	1	10
Shale		5		9
Coal		11	1	1
Sandstone.				
Total thickness of bed	4		3	8
Coal	3	7	2	11

About 30 feet above this last bed described another thinner one occurs as follows:

Section of coal bed at locality 570, about 115 feet above Yankee (?) coal bed.

	Surface.		In entry, 100 feet from opening.	
	Ft.	*in.*	*Ft.*	*in.*
Shale.				
Coal	1	10	1	9½
Shale	1	5	1	2
Coal		6	1	3
Shale.				
Total thickness of bed	3	9	4	2½
Coal	2	4	3	½

The highest bed at this locality that seems to be of economic importance was measured with the following results:

Section of highest coal bed at locality 570.

	Surface.		In entry, 250 feet from opening.	
	Ft.	*in.*	*Ft.*	*in.*
Shale.				
Coal	2		2	8
Shale		10		3
Coal	1	6	2	2
Shale with thin seams of coal	1	6		2
Coal	2		1	3
Shale.				
Total thickness of bed	7	10	6	6
Coal	5	6	6	1

The rocks above the bed last described are not well exposed, but a drill record indicates that some of them are coal-bearing. On the other hand, the occurrence of gravel in several places shows that at east the upper part consists of poorly consolidated sand and gravel that is probably much younger than the coal-bearing rocks.

Farther southeast, at locality 571, a bed of coal lies a few feet above the cliff-making sandstones. Both the stratigraphic position and the character of this bed indicate that it is the same as the lowest bed of coal at locality 570. The section measured here is as follows:

Section of coal bed at locality 571, in Rathbun Canyon.

	Ft.	in.
Shale.		
Coal	1	1
Shale		9
Coal	2	10
Shale		8
Coal		6
Shale.		
Total thickness of bed	5	10
Coal	4	5

None of the higher beds was found near this locality because of poor exposures, and the nearest coal to the south was found in Manco Burro Pass, at locality 572. The lowest coal found occurs practically at the top of the pass, but whether this is the same as the lowest bed in Rathbun Canyon or some higher bed was not ascer-

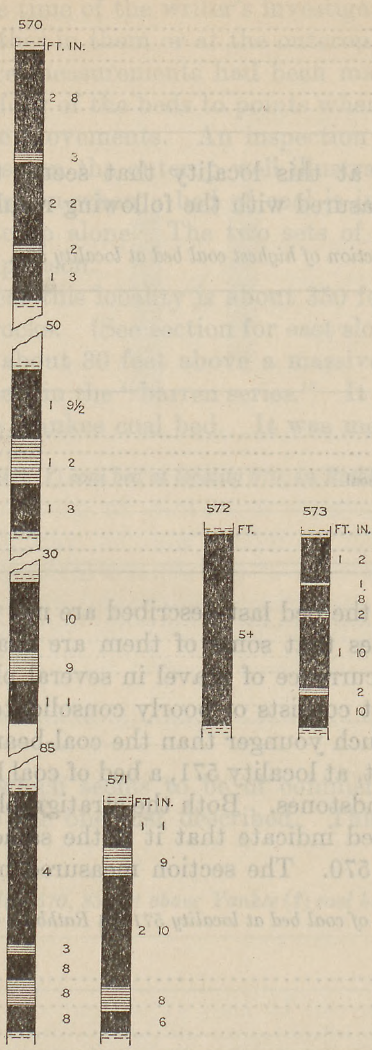

FIGURE 12.—Sections of coal beds in east slope of Barilla Mesa.

tained. At the side of the road to the west, about 100 feet above the pass, a coal bed was opened several years ago, and in the mouth of the old opening the writer found a thickness of 5 feet of coal overlain by shaly sandstone. The bottom of the bed was not exposed. The same bed outcrops in the side of the mesa to the southeast practically at the top of the slope.

Two old openings farther west have about the same altitude as that of locality 572 and may be on this bed. The first one, at locality 573, shows a thickness of 4 feet 4 inches of coal, but this may not be the full thickness of the bed. There seems to have been a considerable opening at this locality at one time, and probably this is the old mine described by St. John as being located on a bed of coal 460 feet above the base of the coal-bearing formation and about 100 feet above the lowest coal bed prospected in Rathbun Canyon. He reports the following section from the old mine:

Section of coal bed at locality 573, in Rathbun Canyon.

	Ft.	in.
Shale.		
Coal	1	2
Shale		1
Coal		8
Shale		2
Coal	1	10
Shale		2
Coal		10
Shale.		
Total thickness of bed	4	11
Coal	4	6

Coal was collected for analysis from this mine 25 feet from the mouth of the entry, where the coal is reported to be 3 to 4 feet thick. One sample, said to have been exposed for 2 or 3 years and doubtless considerably weathered, was sent in 1901 to E. E. Burlingame & Co., of Denver, who analyzed it with the following results:

Analysis of coal from mine at locality 573.

Moisture	2.10
Volatile matter	36.76
Fixed carbon	55.35
Ash	5.51
Sulphur	.28

Specific gravity, 1.04.
Coal produced soft coke.

At locality 574 coal was found 3 feet 4 inches thick, but this may not be the full thickness of the bed.

JOHNSON MESA.

The north slope of Johnson Mesa west of Manco Burro Pass is densely wooded, and no exposures of coal were found on it between this pass and the northward-projecting point of the mesa at locality 575. At this locality a bed of coal 3 feet thick lies a few feet above a massive sandstone at an altitude which indicates that it is probably the Yankee coal bed. About 50 feet above it is another bed which contains 3 feet 7 inches of coal.

Surface indications of these beds were observed in several places in the sides of the mesa southwest of this locality, but no good exposures were found for a distance of about 2 miles. However, at locality 576 one of the higher coal beds of the upper group has been opened in the Llewellyn mine, and in an old prospect opening below this mine a lower bed, according to report is 2 feet 9 inches thick and consists of several benches of shale and bony coal.

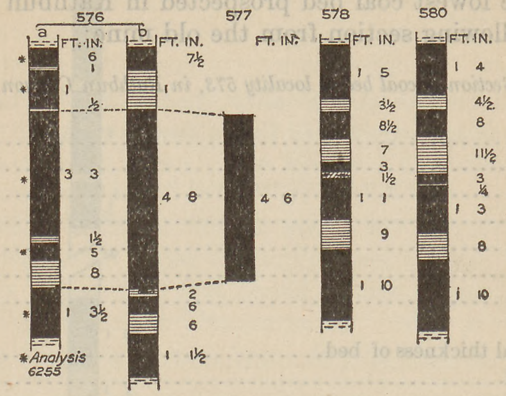

FIGURE 13.—Sections of a coal bed in Johnson Mesa.

Two sections of the coal bed were measured in this mine, one in the first left cross entry off the main entry, where a sample of coal was collected for analysis, and another in the main entry 500 feet from the mine mouth. The results are as follows:

Sections at locality 576, in Llewellyn mine.

	A		B	
	Ft.	*in.*	*Ft.*	*in.*
Shale.				
Coal (sampled at A)		6		7½
Shale		1	1	
Coal (sampled at A)	1		4	8
Bone		½		
Coal (sampled at A)	3	3		
Shale		1½		2
Coal (sampled at A)		5		6
Shale with seams of coal		8		6
Coal (sampled at A)	1	3½	1	1½
Shale.				
Total thickness of bed	7	4½	8	7
Coal sampled	6	5½	....	

A. In first left cross entry off main entry.
B. In main entry, 500 feet from mine mouth.

A sample of this coal was collected by the writer for analysis on July 8, 1908, where the first section was measured. The results are given as analysis 6255 in the table on page 246.

The mine was opened in 1901 and operated for local use for several years but was finally abandoned. It contains a good quality of bituminous coal, and field tests indicated that it probably will coke.

It is black and has vitreous luster, fine texture, and conchoidal fracture. It contains mineral charcoal that shows impressions of reed-like vegetation and grains of yellowish resin. The cleat faces, which trend N. 65° E., are well developed, 3 to 6 inches apart, and extend through the coal but not through the shale partings. The roof of the mine consists of shale that in some places loosens easily. The coal does not disintegrate readily and is comparatively free from bone. It is regarded as a good domestic fuel.

A bed supposed to be Llewellyn coal was penetrated by the drill about a mile northeast of the mine opening, 60 feet below the base of the lava which caps the mesa. Other thin beds of coal were found as shown in the section on Plate XVI (p. 152).

An abandoned opening known as the old Turner mine was found at locality 577, about half a mile northwest of the Llewellyn mine. It is probably on the Llewellyn coal bed, although it is 50 feet lower than the Llewellyn mine and has been regarded locally as being on a lower bed. This mine was opened by John F. Turner in 1902 and operated for local use for about four years. The coal bed was reported by the mine inspector to be 4 feet 6 inches thick. In 1908 the main entry was open for a distance of about 400 feet.

No good exposure of any of the coal beds of the upper group was found for a distance of about 1½ miles west of the old Turner mine. At locality 578 there is an opening known as the old Latimore mine. This mine was opened by G. B. Latimore about 1899 and operated for local use for about five years. The entry had been run in on the coal bed about 400 feet. In 1908 the old entry was accessible for a distance of about 300 feet, although the mine had been abandoned. Two sections of the coal bed were measured in this mine, one at the mouth of the mine and the other 300 feet from the mouth, where a sample of coal was collected for analysis. These sections are as follows:

Sections of coal bed at locality 578, in old Latimore mine.

	A		B	
	Ft.	*in.*	*Ft.*	*in.*
Shale.				
Coal (sampled at B)	1	5	1	1
Shale		3½		2
Coal (sampled at B)		8½		6½
Shale		7		5
Coal (sampled at B)		3		4
Bone		1½		¾
Coal (sampled at B)	1	1	1	1
Shale		9		6½
Coal (sampled at B)	1	10	1	10
Shale.				
Total thickness of bed	7	½	6	¾
Coal sampled	....		4	10½

A. Section measured at mouth of mine.
B. Section measured in the mine 300 feet from the mouth.

The sample of coal was collected for analysis by the writer on July 23, 1908, from a freshly cleared face of the coal bed in the old mine. The results are given as analysis 6287 of the table on page 246.

The coal is black, bituminous, and apparently of coking quality, as indicated by field tests. It is jointed with cleat faces 2 to 3 inches apart which trend N. 75° W. or roughly in the direction of the dip. No work had been done in this mine for four years prior to 1908, yet the roof shale was firm and showed little tendency to fall. It is full of leaf impressions, large palm leaves predominating.

A bed of coal 2 feet thick, with shale above and below it, occurs 52 feet by Locke level above the Latimore mine and is there exposed in a prospect opening.

The old Hobbs mine is a quarter of a mile south of the Latimore mine, at locality 579, and is probably on the same bed. The entry was caved and the mine inaccessible at the time of the writer's investigation. However, Noah A. Owen, who opened the coal beds in this region, states that 6 feet of coal was found in the Hobbs mine and that there are three beds of coal above it, the first one 3 feet 1 inch thick, the second 2 feet 10 inches thick, and the third 4 feet thick.

Still farther south, at locality 580, there is an abandoned opening at the horizon of the Latimore mine known as the old Honeyfield mine. A section was measured in the opening as follows:

Section of coal bed at locality 580, in the old Honeyfield mine.

	Ft.	in.
Shale.		
Coal	1	4
Shale		4½
Coal		8
Shale		11½
Coal		3
Bone		¼
Coal	1	3
Shale		8
Coal	1	10
Shale.		
Total thickness of bed	7	4¼
Coal	5	4

A bed of coal 2 feet 6 inches thick, with shale above and below it, lies 94 feet, by Locke level, above the Honeyfield mine. According to Mr. A. Hallis, who opened it several years ago, this bed contains an excellent quality of coal.

The next place to the south at which coal was found is at locality 581, about half a mile from the old Honeyfield mine. Here some of the rocks are fairly well exposed and several beds of coal were found. At this point a hard quartzose sandstone, locally conglomeratic, lies at the base of the Raton formation, which rests with uneven base on the Trinidad sandstone. It is harder than the sandstone below and

forms a narrow shelf in the exposed ridges. Above this sandstone is the Sugarite coal bed, which has previously been described, and the cliff-making sandstones of the "barren series." The first coal bed above the sandstones is probably the Yankee bed, although only 1 foot 6 inches of coal was found at the outcrop. This coal is crushed by slide rock, and the undisturbed bed probably is thicker. The second coal bed crops out 126 feet higher in the side of the mesa and was measured at the outcrop as follows:

Section of coal bed at locality 581, about half a mile from old Honeyfield mine.

	Ft.	in.
Shale.		
Coal		2
Shale		3
Coal	1	
Shale	1	
Coal	1	6+
Total thickness of bed	3	11+
Coal	2	8+

Only one higher coal bed was found at locality 581. It is 78 feet above the bed just described and is 1 foot 6 inches thick, but this may not be the full thickness of the bed.

In the southern slope of Johnson Mesa coal was found at locality 582, which is 370 feet by barometer above the base of the coal-bearing rocks. The bed was measured as follows:

Section of coal bed at locality 582, on Johnson Mesa.

	Ft.	in.
Shale.		
Coal		6
Shale		2
Coal	2	6
Shale		9
Coal, impure		6
Shale.		
Total thickness of bed	4	5
Coal	3	6

This bed is above a cliff-making sandstone and probably is the Yankee bed. Another exposure of the same bed a quarter of a mile farther east shows coal 2 feet 5 inches thick. Coal 2 feet thick, which was found still farther east, at locality 583, also probably represents the Yankee bed. No indications of any of the higher coals were observed south of Johnson Mesa. The coal-bearing rocks rise toward the east and erosion probably carried the upper coal beds away before the lavas of the mesa were poured out upon the eroded surface.

COAL NEAR YANKEE.

OUTCROPS AND MEASUREMENTS.

On the west slope of Barilla Mesa, northwest of Manco Burro Pass, surface indications of coal were found in the upper coal group in many places, but for a distance of 1½ miles west of the pass no place was found where a satisfactory measurement could be made on any one of the coal beds of the upper group. Farther to the northwest several coal beds have been opened.

At the old Sperry mine, locality 584, one of the lower beds of the upper group has been opened. This mine was operated by Elmer Sperry for several years prior to 1906, when it was purchased by the Yankee Fuel Co. and later closed. The mine had been abandoned prior to the time of the writer's investigation, and little was learned of it except that a drift had been driven in on the bed about 400 feet and that for several years prior to 1906 coal was hauled by wagon from this mine to Raton, where it was used as a domestic fuel. Near the mouth of the mine coal 3 feet 2 inches thick was found, but this may not be the full thickness of the bed.

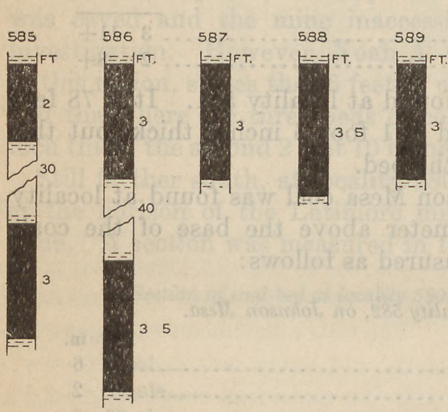

FIGURE 14.—Sections of "Block coal" bed north of Yankee.

The rocks above the mine are not well exposed, but in the side of the mesa 34 feet above the mine a bed of coal 2 feet 4 inches thick, with shale above and below it, was exposed in an old prospect opening, and two other beds crop out at higher levels. One bed, about 140 feet above the Sperry mine, contains 2 feet 5 inches of coal at the outcrop, and the other, 35 feet higher, contains 4 feet or more of coal. The latter bed has been opened in several places near locality 584, but in few of the old openings could details of the bed be obtained. In the opening near locality 584 the bed is 5 feet thick, but the coal is very impure, fully half of the bed consisting of shale and bone. A bed of coal 5 feet 6 inches thick has been reported to occur near this locality, possibly in one of the openings that the writer found inaccessible at the time of his investigation.

In the gulch 300 feet north of the old Sperry mine, at locality 585, two beds of coal have been opened. The lowest bed is 3 feet thick, with shale above and below it, and the one 30 feet higher contains 2 feet of coal with shale above and below it. The lower of these two beds is known locally as the "Block coal" and corresponds in position to the Yankee bed, as it is the lowest of the upper group

of coal beds. At locality 586 a mine was opened on the Block coal bed in 1917, and about 5,000 tons of coal was mined. In the 1,500 feet of the main entry the thickness of the coal ranged from 3 feet to 3 feet 5 inches. One bed 40 feet above the Block coal near this mine contains 3 feet of coal. The Block coal bed has been opened at localities 587, 588, and 589, where the thicknesses are as shown in figure 14.

A bed of coal that is supposed to be the same as the upper one at locality 584 was found at locality 591, and a section on it was measured in a prospect opening 15 feet from the mouth, as follows:

Section of coal bed in prospect at locality 591.

	Ft.	in.
Shale.		
Coal		5
Shale		2
Coal	1	
Shale		2
Coal		8
Shale		1
Coal	1	1
Shale		2
Coal		7
Shale		½
Coal		3
Shale		4
Coal	1	2
Shale.		

This coal was opened at locality 590, where the bed was measured 32 feet from the mouth of the prospect opening as follows:

Section of coal bed in prospect at locality 590.

	Ft.	in.
Shale.		
Coal	1	
Shale		3
Coal	1	9
Shale and coal		4
Coal	1	8
Shale		6
Shale and coal		4
Shale		6
Coal		3
Shale and coal		10
Coal	1	3
Shale		1
Coal		1½
Shale		2½
Coal		9
Shale and coal		11
Shale		2
Coal		1
Shale		7
Coal	1	6
Shale.		

This thick bed of shaly coal was traced at the outcrop for about a mile west of locality 590, but, although prospect openings had been made on it in several places years ago, no place was found where satisfactory measurements of the coal could be made.

At locality 592 a bed of coal that is exposed in an old prospect was measured as follows:

Section of coal bed at locality 592, on Barilla Mesa.

	Ft.	in.
Shale.		
Coal		9
Shale		4
Coal	1	10
Shale		6
Coal, bottom not exposed	1	6+
Total thickness of bed	4	11+
Coal	4	1

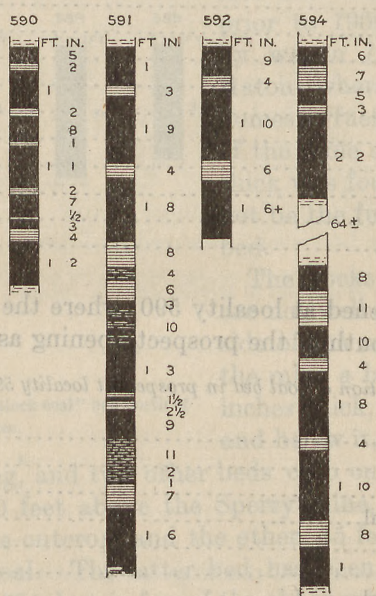

FIGURE 15.—Sections of the highest beds of coal north of Yankee. (The correlation of these sections is questionable.)

At the old Reynolds mine, locality 594, two beds of coal have been opened by two prospect entries which were driven in 280 feet on the lower bed. The coal beds were measured in the mine openings and the intervening strata at the outcrop. The section is as follows:

Section of rocks at locality 594, in Reynolds mine.

	Ft.	in.
Sandstone	12	
Shale, carbonaceous	3	
Coal		6
Shale		7
Coal		5
Shale		3
Coal	2	2
Shale, not well exposed, showing coal blossom in some places	46 ±	
Sandstone, shaly, thin bedded	13	
Shale	5	
Coal		8
Shale		11
Coal		10
Shale		4
Coal	1	8
Shale		4
Coal	1	10
Shale		8
Coal	1	
Shale	14	
Sandstone, massive	28+	
	133±	

The main or lower coal bed consists of five benches of coal separated by shale. So far as determined by the development accomplished at the time of the writer's investigation, the lowest bench of coal is too impure to be of much economic value, but the other four benches contain coal of good quality. The thickness of the several benches differs somewhat from place to place.

The bed was measured and a sample of coal collected for analysis by the writer on July 2, 1908. The measurements are given below. The results of the analysis are given as No. 6244 in the table on page 246.

Section of coal bed in Reynolds mine where sample 6244 was collected.

	Ft.	in.
Shale.		
Coal		7
Shale	1	
Coal (sampled)		9
Shale		3
Coal (sampled)	1	7½
Shale		4½
Coal (sampled)	1	10
Shale		8
Coal, shaly		10
Shale.		
Total thickness of bed	7	11
Coal sampled	4	2½

The coal bed is overlain by sandy shale that forms a strong roof. The cleat faces are well developed and trend N. 10° E. The bed contains a good quality of bituminous coal that probably will coke.

The two beds examined at the Reynolds mine are traceable half a mile west of the mine, and surface indications of still higher beds of coal were found, but no details of these beds were obtained. Between this mine and the Yankee mine the surface where the upper coals should crop out is covered with grass and brush, and no indication of their presence was found.

The Yankee bed or lowest coal of the upper group was mined to some extent west of Yankee several years ago. Yankee mine No. 5 was opened in the gulch at locality 595. The original mine, now abandoned, extended southwestward from this opening, and its main exit was near locality 597, at the end of the shorter incline, not now in use, which is shown on the map (Pl. I). In the main entry, 200 feet west of the mine mouth, the following section of the coal bed was measured:

Section of Yankee coal bed in main entry of Yankee mine, 200 feet from mine mouth.

	Ft.	in.
Shale.		
Coal, bony		9
Shale		3½
Coal		9
Bone		½
Coal		7
Shale	1	
Coal, bony at the base	2	4
Shale.		
Total thickness of bed	5	9
Coal	4	5

Locality 597 is at the end of one of the main entries. In this entry, 1,000 feet west of the mouth, the bed was measured and a sample of the coal collected for analysis by the writer on July 2, 1908, as described below. The results are given as analysis 6243 in the table on page 245.

Section of coal bed measured in Yankee mine No. 3, 1,000 feet from mouth of mine.

	Ft.	in.
Shale.		
Coal, bony (sampled)		10
Bone		1½
Coal (sampled)		6½
Coal, bony		1½
Coal (sampled)		2½
Bone		½
Coal (sampled)		6½
Shale		6
Coal (sampled)	2	1
Coal, bony		6
Shale.		
Total thickness of bed	5	6
Coal sampled	4	2½

Two other samples of coal were collected for analysis from this mine by J. C. Roberts on February 8, 1912, as described below:

Sections of coal bed measured in Yankee mine No. 3.

	Laboratory No. 13365.		Laboratory No. 13366.	
	Ft.	*in.*	*Ft.*	*in.*
Shale.				
Coal (sampled)		5		5
Shale		1½		4
Coal (sampled)	1		1	
Shale		1		1½
Coal (sampled)		7		7
Shale	1		1	3
Coal (sampled)	2	7	2	7
Shale.				
Total thickness of bed	5	9½	6	3½
Coal sampled	4	7	4	7

Sample 13365 was taken at the face of room 2, off the tenth west entry. Sample 13366 was taken at the face of the fifth south entry. The character of a composite of these two samples is shown in analysis 13367 in the table on page 245.

Another measurement of the Yankee coal bed was made farther southwest near locality 596. The main entry of this mine was driven in 1,250 feet on the coal bed, but conditions unfavorable for mining were encountered. The workings had been abandoned before the writer visited the mine in 1908 but were accessible for a short distance. Near the mouth of this entry the coal bed was measured by the writer as follows:

Section of Yankee coal bed at locality 596, in Yankee mine No. 2.

	Ft.	in.
Sandstone.		
Coal		10
Shale		3½
Coal		5½
Bone		1
Coal		3
Bone		½
Coal		6
Shale		3
Coal	2	7½
Shale, carbonaceous.		
Total thickness of bed	5	4
Coal	4	8

Still farther south the Yankee bed was opened south of locality 597 and a prospect entry driven in 250 feet on the coal bed. A section of the bed was measured in this entry 150 feet from the mouth, as follows:

Section of Yankee coal bed at locality 597, in a prospect entry 150 feet from its mouth.

	Ft.	in.
Shale, sandy.		
Coal, impure		6
Shale		3
Coal		10½
Shale		½
Coal		6
Shale		3
Coal, bony near the base	2	6
Shale.		
Total thickness of bed	4	11
Coal	4	4½

About half a mile farther southwest another entry driven in on the Yankee coal bed was found at locality 598. This prospect is locally known as the old Honeyfield mine, and the main entry was run in on the bed 250 feet. The mine was opened in 1904 and furnished coal for domestic use for several years. The entry was caved at the time of the writer's visit in 1908, and the lower part of the bed was not seen. The section measured at the mouth of the old opening is as follows:

Section of Yankee coal bed at locality 598, in old Honeyfield mine.

	Ft.	in.
Sandstone.		
Shale	2	3
Coal		11
Shale		4
Coal	1	6
Shale	2	9
Coal	1	8+
Total thickness of bed	9	5+
Coal	4	1+

OLD YANKEE MINE.

The mine inspector's report for 1906 contains the first published record of output of the Yankee mine. Although mining operations have been carried on in one part or another of the Yankee property since that time, development has been slow. The openings just described, which the writer examined in 1908, were later closed on account of disputes as to title and were inaccessible at the time of his later investigation in 1913. Under later management the openings described below were made, but little coal had been shipped from them previous to 1913. The following description applies mainly to the old workings.

The main entries at localities 595 and 597 were each driven in on the bed about 1,800 feet. These entries were connected by cross entries, but little of the coal thus rendered available was removed, so that the abandonment of the old workings renders practically

useless a considerable body of coal. Unfortunately the maps of this mine were not obtained by the writer, hence the area of the workings can not be shown.

The Yankee bed differs considerably from place to place in thickness and character, and several of the cross entries within the old mine are said to have been abandoned because the coal was too thin or too bony for successful mining under present conditions. The bed is overlain by a soft clay shale that forms an insecure roof, and careful timbering was necessary. In some places the upper bench of coal was left as the roof of the mine.

The coal is black, bituminous, of vitreous to waxy luster, and has fine banded texture and conchoidal fracture. It contains resin in small particles and in irregular-shaped lumps. Mineral charcoal is abundant and shows impressions of reedlike vegetation. Well-developed cleat faces, 3 to 5 inches apart, trend N. 70° E. and extend through the coal but not through the shale partings. The coal disintegrates to some extent when exposed to the weather but not readily enough to deteriorate greatly during shipment.

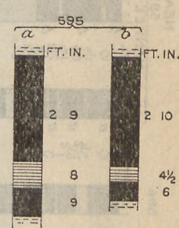

FIGURE 16.—Sections of the Metcalf coal bed, 65 feet above the Yankee coal bed, near locality 595.

The coal from the upper part of the bed in the portion of the mine now abandoned was reported to be very poor. It is separated into thin benches by shale, which adheres to it, and the coal itself is more or less bony. In some parts of the mine the coal above the thickest bench was removed only in the entries where head room was necessary. The floor of the mine gave much trouble. It consists of soft clay shale that creeps and heaves badly. Some of the entries were abandoned because of the rapidity with which this clay was squeezed into them.

Preliminary tests indicate that the Yankee coal is of coking quality, and the inspector of mines[14] gives the following analysis:

Analysis of coal and coke from Yankee.

	Coal.	Coke.
Moisture	0.30	0.60
Volatile matter	41.30	.40
Fixed carbon	50.55	86.65
Sulphur		
Ash	7.85	12.35
	100.00	100.00

[14] U. S. Mine Inspector for New Mexico Terr. Ann. Rept. to Governor of New Mexico for fiscal year ended June 30, 1906, p. 30, 1906.

According to the inspector's statement this coke weighs 12.9 to 13.9 grams to the cubic inch and has a compressive strength ranging from 2,000 to 2,150 pounds.

The double-entry room and pillar system of mining was followed. The entries were driven in a general northwesterly direction or down the dip, but there was not enough water in the mine to render the lack of natural drainage disadvantageous. The coal was undercut by hand, hauled to the mouth of the mine by mules, and lowered over a 3-rail gravity incline 3,300 feet long to a tipple that was equipped with revolving screen, picking table, scales, and other devices, where it was loaded into railway cars for shipment. A railway known as the Santa Fe, Raton & Eastern connects Yankee with the main line of the Atchison, Topeka & Santa Fe Railway at Raton.

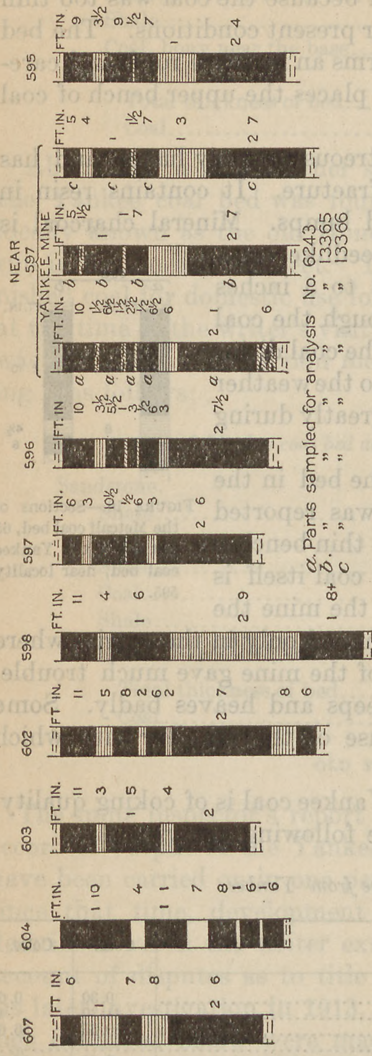

FIGURE 17.—Sections of the Yankee coal bed near Yankee.

NEW YANKEE MINE.

In 1913 a new opening, which utilized a part of the old No. 5 entry, was being made in the Yankee bed near locality 595. A new incline had been constructed to this opening and was being extended to an opening on the higher beds at locality 600, which is described below.

In the new openings in the Yankee bed the mine superintendent, Mr. H. L. Handley, made systematic measurements to show the variations of this bed. The sections, measured 50 feet apart, are platted on Plate XXII. The location of each is indicated by the distance in the cross entries measured from the main entry. This series of sections gives the best available information of the character of the Yankee bed and hence is given in full. The sections show that a bench of coal fairly uniform in thickness occurs at the bottom of the bed and is separated from the higher benches by a shale of relatively uniform thickness. This lower bench

SECTIONS OF THE YANKEE COAL BED.

Measured in the Yankee mine at intervals of 50 feet. Vertical scale, 5 feet to 1 inch. Figures above columns give distances in feet from main entry.

contains the commercially valuable coal. The coal of the upper part of the bed is more irregular. In some places it is separated by partings of shale into distinct benches, but these partings are not persistent.

The difficulty of describing the coal beds of the upper group from the indications at the surface is well illustrated in the sections measured in the thirteenth west entry. The opening, although started at the level of the coal bed, was driven 100 feet through surface débris without finding the coal and nearly 200 feet before the bed was found in full thickness.

A bed of coal known locally as the Metcalf bed occurs about 65 feet above the Yankee bed. It was observed in a prospect opening above the Yankee mine, where section A in the table below was measured. The same bed has been opened in the gulch above the mine opening, locality 595, where section B was measured. The results are as follows:

Section of Metcalf coal bed near locality 595.

	A		B	
	Ft.	in.	Ft.	in.
Shale.				
Coal		8	(?)	
Shale	2	7	(?)	
Coal	2	9	2	10
Shale		8		4½
Coal		9		6
Shale.				
Total thickness of bed	7	5	3	8½+
Coal	4	2	3	4+

A. Section measured in prospect opening above Yankee mine.
B. Section measured in gulch above locality 595.

During the summer of 1913 the incline to the Yankee bed was extended to openings in the highest or Kellog coal at localities 600 and 601. At the time of the writer's investigation in 1913 the entry at 600 had been driven 750 feet N. 20° E. from the opening. Two sections were measured in this entry, the first 200 feet from the opening and the second at the end of the entry, where a sample of the coal for analysis was collected by K. C. Heald on September 17, 1913. The sections are as follows:

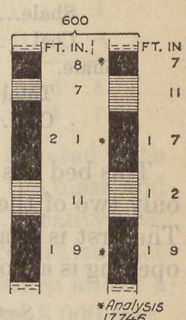

FIGURE 18.—Sections of the Kellog coal bed northwest of Yankee.

Sections of coal bed at locality 600.

	A		B	
	Ft.	in.	Ft.	in.
Shale.				
Coal (sampled at B)		8		7
Shale		7		11
Coal (sampled at B)	2	1	1	7
Shale		11	1	2
Coal (sampled at B)	1	9	1	9
Shale.				
Total thickness of bed	6		6	
Coal sampled	....		3	11

A. Section measured 200 feet within entry at locality 600.
B. Section measured at end of entry at locality 600.

The results of the analysis are given as No. 17746 in the table on page 245.

AREA BETWEEN YANKEE AND RATON.

In the southern slope of Horse Mesa, where the section described on page 147 was measured, the Yankee coal bed is well exposed at locality 602 and was measured at the outcrop as follows:

Section of Yankee coal bed at locality 602, in Horse Mesa.

	Ft.	in.
Shale.		
Coal		11
Shale		5
Coal		8
Shale		2
Coal		6
Shale		2
Coal	2	7
Shale		8
Coal		6
Shale.		
Total thickness of bed	6	7
Coal	5	2

This bed has been prospected in a few places east of Sugarite, but at only two of these openings were good sections obtained by the writer. The first is near locality 603. The section measured in this prospect opening is as follows:

Section of Yankee coal bed at locality 603, east of Sugarite.

	Ft.	in.
Shale.		
Coal		11
Shale		3
Coal	1	5
Shale		4
Coal	2	
Shale.		
Total thickness of bed	4	11
Coal	4	4

The second measurement was made in a prospect opening in the gulch above the southernmost opening of the Sugarite mine, at locality

604. The altitude indicates that this prospect is probably on the Yankee bed, but, if so, the upper benches found at locality 602 are either not exposed in the prospect or have disappeared in the interval between these two localities. The section measured at this locality is as follows:

Section of coal bed at locality 604, near Sugarite mine.

	Ft.	in.
Shale.		
Coal	1	2
Shale		1
Coal	2	2
Shale.		
Total	3	5
Coal	3	4

Near the head of this gulch, at locality 604 (location approximate) a prospect entry has been driven in about 50 feet on one of the higher coal beds of the upper group. In this entry the section of the bed is as follows:

Section of coal bed at locality 604, near head of gulch east of Sugarite mine.

	Ft.	in.
Shale.		
Coal	1	10
Shale		4
Coal	1	1
Shale		7
Coal		8
Shale		1
Coal		6
Shale		1
Coal		6
Shale.		
Total thickness of bed	5	8
Coal	4	7

The west slope of Horse Mesa north of Sugarite is covered with fragments of basalt derived from the sheet at the top of the mesa and with a dense growth of underbrush. At only one place, locality 605, was coal found in the upper coal-bearing zone. There are surface indications here of two beds of coal of considerable thickness above a prominent cliff-making sandstone, at an altitude of about 8,000 feet, but at no place could the thickness or character of these beds be satisfactorily ascertained without extensive prospecting. At one point, however, 2 feet of coal was found in the lower bed with shale above and below it, but it is not probable that this is the full thickness of the bed, for here the surface rocks had evidently slumped to some extent. Surface indications of at least two other beds of coal at lower horizons were found near by. The same beds were found in the opposite wall of Chicorica Canyon at locality 606, but they were not well exposed and no satisfactory measurements of the coal beds were obtained.

Farther north, in the west branch of the canyon of Chicorica Creek about a mile west of the fork, near the Colorado State line, a bed of coal that is reported to be 5 feet thick occurs above a prominent sandstone at an altitude of nearly 8,000 feet. Two thinner beds were observed north of the reservoir between the forks of the creek at lower altitudes, but no satisfactory measurements could be made of them.

West and south of Sugarite surface indications of the upper coals were observed in several places, but no good exposure was found north of the southernmost point of Bartlett Mesa, where the section described on page 144 was measured. The Yankee bed was found here at locality 607, about 435 feet above the base of the coal-bearing rocks. Its character is shown by surface measurements as follows:

Section of Yankee coal bed at locality 607, in point of Bartlett Mesa.

	Ft.	in.
Shale.		
Coal		6
Shale	1	
Coal		7
Shale		8
Coal	2	6
Shale.		
Total thickness of bed	5	3
Coal	3	7

The thickest coal bed of the section measured in the side of the mesa crops out in the ridge near the point of the mesa, above locality 606. This bed has the following section:

Section of coal bed just above locality 608, in Bartlett Mesa.

	Ft.	in.
Sandstone.		
Coal	2	
Shale	1	
Coal		6
Shale	1	7
Coal	1	10
Shale	1	6
Coal	1	
Shale.		
Total thickness of bed	9	5
Coal	5	4

Little is known of the upper coals of Bartlett Mesa for a considerable distance west of this point. Indications of their presence were found in several places in Linwood Canyon, but the exposures are so poor that little dependence can be placed on them as indicating the thickness and character of the beds. Several of these beds were found in the section measured east of Linwood Canyon, described on page 146. (See also section 335, Pl. XVI.) This section was measured before the economic study of the field was undertaken, at a time when the general stratigraphic relations of the coal beds were desired

rather than the details of the separate beds. Also the exact localities can not be indicated on the map, which was made after the section was measured. No rocks were exposed here at the horizon where the Yankee bed should crop out, but about 85 feet higher a bed of shaly coal was found. The lower 3 feet consists of fairly clean coal, but the upper 2 feet of the bed consists of alternating layers of coal and shale. Another bed 6 feet thick occurs about 60 feet higher and consists of coal and shale in alternating layers. Another bed of coal that may have some commercial value was found about 125 feet higher. The bed is 5 feet thick, but the coal is shaly. The cleanest coal in this section occurs at an altitude of 7,700 feet, by barometer, and is 3 feet thick with shale above and below it.

The next place to the west at which these coal beds were observed is in the point of the mesa north of Raton, where the section given below was measured at locality 608. Here the lowest coal of the upper group is 1 foot 8 inches thick with shale above and below it. It is 373 feet, by Locke level, above the base of the Raton formation, a distance that suggests the Yankee bed. A massive sandstone above it, however, renders this correlation doubtful, and a coal bed 156 feet higher may be the Yankee coal. This bed was measured in detail as follows:

Section of coal bed at locality 608, in point of Mesa north of Raton.

	Ft.	in.
Shale.		
Coal	1	4
Shale		6
Coal	1	6
Shale	1	
Coal, with thin partings of shale	2	
Shale.		
Total thickness of bed	6	4
Coal	4	10

In the west side of the gulch at locality 609 this bed is well exposed with the following section:

Section of coal bed at locality 609, in south side of gulch.

	Ft.	in.
Shale.		
Coal	1	6
Shale		5
Coal		7
Shale		6
Coal	1	6
Bone		3
Coal		4
Shale.		
Total thickness of bed	5	1
Coal	3	11

The details of a still higher bed measured at the outcrop near locality 609 are as follows:

Section of coal bed near locality 609, in gulch north of Raton.

	Ft.	in.
Shale.		
Coal	1	8
Shale	1	4
Coal	1	
Shale	1	
Coal and shale in alternating layers	1	4
Shale.		
Total thickness of bed	6	4
Coal	4	

A coal bed about 750 feet above the base of the Raton formation contains 4 feet 10 inches of clean coal with shale above and below it. This is possibly the Savage Canyon coal, which occurs farther north—down the dip—at altitudes slightly lower than 7,500 feet.

Another bed of clean coal 2 feet 4 inches thick with shale above and below it lies 164 feet higher, by Locke level. Although this bed contains much better coal than that which crops out at the Raton Tunnel, it occurs at an altitude which suggests that it may be the Tunnel coal.

ANALYSES OF COAL.

The quality of the coal contained in the several beds has already been described in connection with the mines, but may be summarized as follows: All the coal of the Raton field is bituminous, of relatively high rank, and much of it will coke. It differs somewhat in chemical composition and in heating value, as shown in the analyses. In practical use, however, the variations in composition are much more apparent, doubtless due to physical differences. With some apparent exceptions, the coal of the oldest beds—those of Cretaceous age—is the highest in rank, forms the best coke, and is most highly prized as steam-producing fuel. The coal of the younger beds—those of Tertiary age—is relatively lighter, forms weaker coke or is noncoking, burns freely, and in general has lower heating value. The samples of coal from which the analyses were made were all collected in the manner prescribed by the United States Geological Survey to insure uniformity in character. There are, however, three classes of samples presented: (1) Unless otherwise stated in the table, the sample was collected at a working face in a mine actively in operation at the time the sample was taken. (2) Some of the samples, as noted, were taken in abandoned mines from faces freshly cleared of weathered coal, so that they represent coal that is slightly, if at all, changed because of exposure. (3) Mined coal, car samples, "slack," and similar material as noted in the table.

The Raton coal, or the oldest bed in the field, has been most extensively mined and hence is better known than any of the younger beds. It is represented in the following table by nineteen analyses. Of these the nine mine samples show an average heating value of 14,990 British thermal units for the pure coal, free from ash and moisture. The next younger coal, the Sugarite, has been mined only in Chicorica Canyon. This is a freely burning noncoking coal and theoretically should be a coal of lower rank than the Raton coal, yet the analyses of the three mine samples indicates a slightly higher heating value, the average for the coal free from ash and moisture being 15,010 British thermal units. This comparison may be misleading because of the number of analyses averaged. Also, the nine samples of the Raton coal represent a considerable area and one in which the coal has been affected by intrusions of igneous rock. The three from the Sugarite coal represent a very restricted area. Possibly the large amount of resin in the Sugarite coal makes its heating value greater than it would have been without the resin.

Some of the coals of the upper group will coke, but the coke is inferior to that made from the Raton coal. They are all much more brittle than the older coal and hence are more easily mined. The fuel value of some of them is notably lower than that of the older coals, although in some samples this value was unexpectedly high. Of the sixteen samples representing this group, the seven mine samples gave an average of 14,810 British thermal units for the coal free from ash and moisture.

The analysis of each sample is given in the table in four forms, marked A, B, C, and D. Analysis A represents the condition of the coal at the point in the mine from which the sample was cut. Analysis B shows the condition of the sample after drying at a temperature slightly above the normal until its weight remains constant. Analysis C gives the theoretical condition of the coal after all the moisture has been expelled. Analysis D represents the coal free from both moisture and ash. This is supposed to represent the true coal substance free from the principal impurities. Forms C and D are obtained from the others by recalculation. They should not be used for ordinary comparison, as they represent theoretical conditions that never exist.

Analyses of samples of coal from the Raton coal field.

[Made at the Pittsburgh laboratory of the Bureau of Mines.]

Raton coal bed—Vermejo formation.

Name of mine.	No. on map (Pl. I.)	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate. Moisture.	Proximate. Volatile matter.	Proximate. Fixed carbon.	Proximate. Ash.	Ultimate. Sulphur.	Ultimate. Hydrogen.	Ultimate. Carbon.	Ultimate. Nitrogen.	Ultimate. Oxygen.	Heating value. Calories.	Heating value. British thermal units.
Koehler mine	103	14796	1.0	A	2.3	35.9	49.9	11.85	0.63	5.17	71.27	1.34	9.74	7,180	12,920
				B	1.3	36.2	50.5	11.97	.64	5.11	71.99	1.35	8.94	7,250	13,050
				C	......	36.7	51.2	12.13	.65	5.03	72.98	1.37	7.84	7,350	13,230
				D	......	41.8	58.2	......	.74	5.72	83.05	1.56	8.93	8,365	15,060
Do	......	12335	3.4	A	5.0	36.3	49.0	9.7	.62	......	......	......	......	......	......
				B	1.6	37.6	50.7	10.1	.64	......	......	......	......	......	......
				C	......	38.2	51.5	10.3	.65	......	......	......	......	......	......
				D	......	42.6	57.4	......	.72	......	......	......	......	......	......
Do	105	12336	1.3	A	3.1	36.6	48.3	12.0	.78	......	......	......	......	......	......
				B	1.8	37.1	49.0	12.1	.79	......	......	......	......	......	......
				C	......	37.8	49.9	12.3	.80	......	......	......	......	......	......
				D	......	43.1	56.9	......	.91	......	......	......	......	......	......
Do	......	12337	1.0	A	2.9	35.3	47.2	14.6	.48	......	......	......	......	......	......
				B	1.9	35.6	47.7	14.8	.48	......	......	......	......	......	......
				C	......	36.3	48.6	15.1	.49	......	......	......	......	......	......
				D	......	42.8	57.2	......	.58	......	......	......	......	......	......
Koehler mine; Composite of samples 12335, 12336, and 12337.	......	12338	1.9	A	3.6	36.1	48.3	12.00	.70	5.25	69.76	1.31	10.98	7,015	12,620
				B	1.8	36.8	49.2	12.23	.71	5.14	71.11	1.34	9.47	7,150	12,870
				C	......	37.5	50.1	12.45	.73	5.03	72.40	1.36	8.03	7,280	13,100
				D	......	42.8	57.2	......	.83	5.75	82.70	1.55	9.17	8,315	14,960
Koehler mine	137	17781	.4	A	2.0	35.7	4,.2	13.10	.78	5.24	70.71	1.32	8.85	7,035	12,670
				B	1.6	35.9	49.4	13.15	.78	5.22	70.99	1.33	8.53	7,065	12,720
				C	......	36.4	50.2	13.36	.80	5.12	72.13	1.35	7.24	7,180	12,920
				D	......	42.1	57.9	......	.92	5.91	83.25	1.56	8.36	8,285	14.910
Do	97	33017	.9	A	2.3	36.8	50.0	10.90	.71	5.19	72.28	1.34	9.58	7,215	12,990
				B	1.4	37.2	50.4	11.00	.72	5.14	72.93	1.35	8.86	7,280	13,100
				C	......	37.7	51.1	11.16	.73	5.05	74.01	1.37	7.68	7,385	13,300
				D	......	42.4	57.6	......	.82	5.68	83.31	1.54	8.65	8,315	14,970
Do	129	33018	.9	A	2.5	36.7	49.3	11.48	.70	5.22	71.59	1.35	9.66	7,120	12,820
				B	1.6	37.0	49.8	11.58	.71	5.17	72.23	1.36	8.95	7,185	12,930
				C	......	37.6	50.6	11.77	.72	5.07	73.41	1.38	7.65	7,300	13,140
				D	......	42.7	57.3	......	.82	5.75	83.20	1.56	8.67	8,275	14,900
Willow mine No. 6	......	6930	1.5	A	2.8	33.3	51.5	12.37	1.19	5.26	71.59	1.24	8.35	7,065	12,720
				B	1.3	33.8	52.3	12.56	1.21	5.17	72.68	1.26	7.12	7,175	12,910
				C	......	34.2	53.1	12.73	1.22	5.08	73.68	1.28	6.01	7,270	13,090
				D	......	39.2	60.8	......	1.40	5.82	84.43	1.47	6.88	8,330	15,000
Willow mine No. 3	......	3221	1.0	A	2.5	35.5	52.9	9.1	.72	......	......	......	......	7,295	13,130
				B	1.5	35.8	53.5	9.2	.73	......	......	......	......	7,365	13,260
				C	......	36.4	54.2	9.4	.74	......	......	......	......	7,480	13,460
				D	......	40.1	59.9	......	.82	......	......	......	......	8,255	14,860
Do	......	3222	2.0	A	3.5	33.0	50.6	12.9	.64	......	......	......	......	......	......
				B	1.5	33.7	51.6	13.2	.65	......	......	......	......	......	......
				C	......	34.2	52.4	13.4	.66	......	......	......	......	......	......
				D	......	39.5	60.5	......	.77	......	......	......	......	......	......
Willow mine No. 1	......	32592	.8	A	2.3	36.2	50.5	11.00	.83	5.33	72.45	1.37	9.02	7,170	12,910
				B	1.6	36.5	50.8	11.09	.84	5.28	73.02	1.38	8.39	7,230	13,010
				C	......	37.0	51.7	11.27	.85	5.19	74.20	5.40	7.09	7,345	13.220
				D	......	41.8	58.2	......	.96	5.85	83.62	1.48	7.99	8,280	14,900
Willow mine No. 4	......	32593	.8	A	2.6	35.1	50.4	11.86	.56	5.27	71.41	1.34	9.56	7,055	12,700
				B	1.9	35.3	50.8	11.95	.56	5.23	71.95	1.35	8.96	7,105	12,970
				C	......	36.0	51.8	12.18	.58	5.11	73.35	1.38	7.40	7,245	13,040
				D	......	41.0	59.0	......	.66	5.82	83.52	1.57	7.43	8,250	14,850
Car sample, run-of-mine coal of Willow mine	......	3295	2.0	A	3.4	32.1	47.8	16.67	.73	4.95	66.19	1.23	10.23	6,605	11,890
				B	1.5	32.7	48.8	17.01	.74	4.83	67.54	1.25	8.63	6,740	12,140
				C	......	33.2	49.5	17.26	.76	4.73	68.55	1.27	7.43	6,845	12,320
				D	......	40.1	59.9	......	.91	5.72	82.86	1.54	8.97	8,270	14,890
Willow mine No. 5	179	6417	1.4	A	2.4	33.7	54.4	9.47	.66	5.21	72.84	1.10	10.72	7,305	13,150
				B	1.0	34.2	55.2	9.60	.67	5.12	73.87	1.12	9.62	7,405	13,330
				C	......	34.5	55.8	9.70	.68	5.06	74.65	1.13	8.78	7,485	13,470
				D	......	38.2	61.8	......	.75	5.60	82.67	1.25	9.73	8,290	14,920
Do	179	6418	1.5	A	2.5	34.7	54.0	8.82	.76	5.50	73.65	1.20	10.70	7,405	13,330
				B	1.0	35.2	54.8	8.95	.77	5.41	74.77	1.22	8.88	7,515	13,530
				C	......	35.5	55.4	9.05	.78	5.35	75.54	1.23	8.05	7,595	13,670
				D	......	39.1	60.9	......	.86	5.88	83.06	1.35	8.85	8,350	15,030
Do	......	6931	1.3	A	2.4	34.5	53.3	9.8	.64	......	......	......	......	7,320	13,180
				B	1.1	35.0	54.0	9.9	.65	......	......	......	......	7,415	13,350
				C	......	35.4	54.6	10.0	.66	......	......	......	......	7,505	13,510
				D	......	39.3	60.7	......	.73	......	......	......	......	8,335	15,010

Analyses of samples of coal from the Raton coal field—Continued.

Raton coal bed—Vermejo formation—Continued.

Name of mine.	No. on map (Pl. I.).	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate. Moisture.	Proximate. Volatile matter.	Proximate. Fixed carbon.	Proximate. Ash.	Ultimate. Sulphur.	Ultimate. Hydrogen.	Ultimate. Carbon.	Ultimate. Nitrogen.	Ultimate. Oxygen.	Heating value. Calories.	Heating value. British thermal units.
New Dutchman mine	282	3226	1.2	A	2.2	33.2	52.2	12.4	0.75					7,240	13,030
				B	1.1	33.6	52.8	12.5	.76					7,325	13,190
				C		34.0	53.4	12.6	.77					7,405	13,330
				D		38.9	61.1		.88					8,480	15,260
Do	278	3227	1.2	A	2.3	33.0	51.6	13.1	.66						
				B	1.1	33.4	52.2	13.3	.67						
				C		33.8	52.8	13.4	.68						
				D		39.0	61.0		.78						
Car sample, run-of-mine coal of New Dutchman mine		3294	1.4	A	2.7	31.8	50.9	14.57	.69	4.88	69.96	1.17	8.73	6,965	12,540
				B	1.3	32.3	51.6	14.78	.70	4.79	70.95	1.19	7.59	7,065	12,720
				C		32.7	52.3	14.98	.71	4.71	71.92	1.20	6.48	7,160	12,890
				D		38.5	61.5		.83	5.54	84.58	1.41	7.64	8,420	15,160
Gardiner mine (new)	283	14795	.9	A	2.4	36.7	45.7	15.23	.64	5.13	67.91	1.30	9.79	6,810	12,260
				B	1.4	37.0	46.2	15.37	.65	5.08	68.53	1.31	9.06	6,870	12,370
				C		37.6	46.8	15.60	.66	4.99	69.54	1.33	7.88	6,970	12,550
				D		44.5	55.5		.78	5.91	82.39	1.58	9.34	8,260	14,870
Dawson mine No.2		18166	1.1	A	2.2	35.7	48.3	13.8	.68					6,985	12,570
				B	1.2	36.1	48.8	13.9	.69					7,060	12,700
				C		36.5	49.4	14.1	.70					7,145	12,860
				D		42.5	57.5		.81					8,315	14,960
Do		18169	.9	A	2.3	35.1	44.6	18.0	.69					6,645	11,960
				B	1.4	35.4	45.0	18.2	.70					7,705	12,070
				C		35.9	45.7	18.4	.71					6,805	12,250
				D		44.0	56.0		.87					8,340	15,010
Do		18171	.7	A	2.3	38.1	48.8	10.8	.60					7,275	13,100
				B	1.5	38.5	49.1	10.9	.60					7,330	13,200
				C		39.1	49.9	11.0	.61					7,445	13,400
				D		43.9	56.1		.69					8,370	15,600
Do		18174	1.4	A	2.5	37.3	48.4	11.8	.69					7,150	12,870
				B	1.2	37.8	49.0	12.0	.70					7,245	13,050
				C		38.2	49.6	12.2	.71					7,335	13,200
				D		43.5	56.5		.81					8.350	15,030
Do		18175	.6	A	2.5	36.9	46.3	14.3	.74					6,990	12,580
				B	1.9	37.1	46.6	14.4	.74					7,035	12,660
				C		37.8	47.5	14.7	.76					7,170	12,910
				D		44.3	55.7		.89					8,405	15,130
Dawson mine No. 2; composite of samples 18166, 18169, 18171, 18174, and 18175.		18279	.9	A	2.4	36.7	47.1	13.77	.65	5.17	69.97	1.37	9.07	7,000	12,600
				B	1.5	37.1	47.5	13.90	.66	5.12	70.63	1.38	8.31	7,070	12,720
				C		37.7	48.2	14.11	.67	5.02	71.71	1.40	7.09	7,175	12,920
				D		43.8	56.2		.78	5.84	83.49	1.63	8.26	8,355	15,040
Dawson mine No. 2		256-D	.7	A	2.2	37.9	45.1	14.8	.69					6,990	12,590
				B	1.5	38.2	45.4	14.9	.69					7,040	12,670
				C		38.8	46.1	15.1	.71					7,145	12,870
				D		45.7	54.3		.83					8,420	15,160
Do		6606	1.9	A	3.1	32.2	49.4	15.3	.71					6,800	12,240
				B	1.2	32.9	50.4	15.5	.72					6,930	12,480
				C		33.3	51.0	15.7	.73					7,015	12,630
				D		39.5	60.5		.87					8,325	14,990
Dawson mine No. 2; composite of two mine samples		12235	1.7	A	3.3	35.7	48.7	12.34	.71	5.31	70.35	1.19	10.10	7,085	12,760
				B	1.6	36.3	49.5	12.55	.72	5.21	71.57	1.21	8.74	7,210	12,980
				C		36.9	50.3	12.76	.73	5.11	72.76	1.23	7.41	7,330	13,190
				D		42.3	57.7		.84	5.86	83.40	1.41	8.49	8,400	15,120
Dawson mine No. 5	306	33020	.7	A	2.1	37.9	49.4	10.61	.67	5.30	73.20	1.35	8.87	7,325	13,190
				B	1.4	38.1	49.8	10.68	.67	5.26	73.69	1.36	8.34	7,375	13,270
				C		38.7	50.5	10.84	.68	5.18	74.77	1.38	7.15	7,480	13,470
				D		43.4	56.6		.76	5.81	83.86	1.55	8.02	8,390	15,110
Do	316	33021	1.1	A	2.7	33.6	45.7	18.00	.71	4.87	66.18	1.24	9.00	6,545	11,790
				B	1.6	34.0	46.2	18.20	.72	4.80	66.92	1.25	8.11	6,620	11,920
				C		34.5	47 0	18.50	.73	4.70	68.01	1.27	6.79	6,730	12,110
				D		42.4	57.6		90	5.77	83.45	1.56	8.32	8,255	14,860
Dawson mine No. 9	293	33019	1.1	A	2.7	35.2	47.7	14.36	.58	4.95	68.77	1.25	10.09	6,810	12,260
				B	1.6	35.6	48.3	14.52	.59	4.88	69.55	1.26	9.20	6,885	12,400
				C		36.2	49.1	14.75	.60	4.78	70.66	1.28	7.93	6,995	12,590
				D		42.5	57.5		.70	5.61	82.88	1.50	9.31	8,205	14,770
Dawson mine No. 6	322	33022	.5	A	1.8	37.1	46.4	14.67	.57	5.18	69.40	1.31	8.87	6,940	12,490
				B	1.3	37.3	46.6	14.75	.57	5.15	69.78	1.32	8.43	6,980	12,560
				C		37.8	47.2	14.95	.58	5.06	70.70	1.33	7.38	7,070	12,730
				D		44.5	55.5		.68	5.95	83.13	1.56	8.68	8,315	14,960

Analyses of samples of coal from the Raton coal field—Continued.

Coal beds in Raton formation.

Name of mine.	No. on map (Pl. I.).	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate: Moisture.	Proximate: Volatile matter.	Proximate: Fixed carbon.	Proximate: Ash.	Sulphur.	Ultimate: Hydrogen.	Ultimate: Carbon.	Ultimate: Nitrogen.	Ultimate: Oxygen.	Heating value: Calories.	Heating value: British thermal units.
Wagon mine	339	6286	0.5	A	2.1	36.1	50.2	11.60	0.64	4.94	69.96	1.33	11.53	7,205	12,970
				B	1.6	36.2	50.5	11.66	.64	4.90	70.31	1.34	11.15	7,240	13,030
				C		36.8	51.3	11.85	.65	4.80	71.48	1.36	9.86	7,360	13,250
				D		41.8	58.2		.74	5.45	81.09	1.54	11.18	8,350	15,030
Sugarite mine No. 1	343	14791	2.1	A	3.9	38.1	49.1	8.93	.56	5.71	72.37	1.58	10.85	7,265	13,070
				B	1.8	38.9	50.2	9.12	.57	5.60	73.92	1.61	9.18	7,420	13,350
				C		39.6	51.1	9.29	.58	5.49	75.25	1.64	7.75	7,550	13,590
				D		43.7	56.3		.64	6.05	82.96	1.81	8.54	8,325	14,990
Sugarite mine No. 2	355	14792	1.0	A	2.9	39.7	48.7	8.70	.51	5.62	73.52	1.57	10.08	7,380	13,280
				B	1.9	40.1	49.2	8.79	.52	5.57	74.26	1.59	9.27	7,455	13,420
				C		40.9	50.1	8.96	.53	5.46	75.73	1.62	7.70	7,600	13,680
				D		44.9	55.1		.58	6.00	83.18	1.78	8.46	8,350	15,030
Hartsel mine (abandoned)	346	6285	2.0	A	5.4	34.0	47.9	12.7	.68					6,440	11,590
				B	3.5	34.7	48.9	12.9	.69					6,570	11,830
				C		35.9	50.7	13.4	.72					6,805	12,250
				D		41.5	58.5		.83					7,860	14,140
Scoop prospect	375	6284	5.1	A	9.78	33.11	47.54	9.57	.52						
				B	4.93	34.89	50.10	10.08	.55						
				C		36.70	52.69	10.61	.58						
				D		41.06	58.94		.65						
Brilliant mine	512	17703	.9	A	2.6	36.0	45.3	16.08	.56	5.35	67.63	1.56	8.82	6,750	12,150
				B	1.7	36.4	45.7	16.23	.57	5.30	68.25	1.57	8.08	6,810	12,260
				C		37.0	46.5	16.51	.57	5.19	69.43	1.60	6.70	6,930	12,470
				D		44.3	55.7		.68	6.22	83.16	1.92	8.02	8,300	14,940
Do		3228	1.0	A	2.2	36.0	50.7	11.1	.57					7,255	13,060
				B	1.2	36.3	51.3	11.2	.58					7,330	13,200
				C		36.8	51.9	11.3	.58					7,420	13,360
				D		41.5	58.5		.66					8,370	15,070
Do		3229	1.3	A	2.7	36.2	51.3	9.8	.58						
				B	1.4	36.7	51.9	10.0	.59						
				C		37.2	52.7	10.1	.60						
				D		41.4	58.6		.66						
Brilliant mine; car sample, run-of-mine coal		3331	1.4	A	2.8	34.3	48.3	14.57	.61	5.06	68.51	1.51	9.74	6,830	12,290
				B	1.4	34.8	49.0	14.78	.62	4.97	69.48	1.53	8.62	6,925	12,470
				C		35.3	49.7	14.99	.63	4.89	70.47	1.55	7.47	7,025	12,650
				D		41.5	58.5		.74	5.75	82.89	1.83	8.79	8,265	14,875
Red Robin mine (Wootton, Colo.)		257-D	.6	A	2.3	36.1	47.0	14.6	.63					6,960	12,530
				B	1.7	36.3	47.3	14.7	.63					7,000	12,600
				C		37.0	48.1	14.9	.65					7,125	12,830
				D		43.5	56.5		.76					8,380	15,080
Do		258-D	.3	A	2.1	34.6	49.5	13.8	.68						
				B	1.7	36.3	47.3	14.7	.68						
				C		35.3	50.6	14.1	.69						
				D		41.1	58.9		.80						
Red Robin mine; car sample, run-of-mine coal		345-D	.6	A	2.8	33.1	45.3	18.82	.62	4.83	64.45	1.17	10.11	6,490	11,680
				B	2.2	33.3	45.6	18.93	.62	4.79	64.84	1.18	9.64	6,530	11,750
				C		34.1	46.5	19.36	.64	4.65	66.29	1.20	7.86	6,675	12,020
				D		42.2	57.8		.79	5.77	82.20	1.49	9.75	8,277	14,900
Yankee mine No. 3 (Yankee bed)		6243	2.4	A	5.0	36.8	46.2	12.00	.56	5.15	66.01	1.28	15.00	6,700	12,060
				B	2.7	37.7	47.3	12.29	.57	5.00	67.63	1.31	13.20	6,865	12,360
				C		38.7	48.7	12.63	.59	4.83	69.50	1.35	11.10	7,055	12,700
				D		44.3	55.7		.68	5.53	79.54	1.55	12.70	8,075	14,540
Do		13365	3.4	A	5.2	37.0	48.3	9.5	.56						
				B	1.9	38.3	49.9	9.9	.58						
				C		39.0	50.9	10.1	.59						
				D		43.4	56.6		.66						
Do		13366	4.4	A	6.1	35.2	42.1	16.6	.53						
				B	1.7	36.9	44.0	17.4	.55						
				C		37.5	44.8	17.7	.56						
				D		45.6	54.4		.68						
Yankee mine No. 3; composite of samples 13365 and 13366.		13367	3.9	A	5.6	35.8	45.4	13.17	.55	5.31	66.76	1.18	13.03	6,675	12,020
				B	1.8	37.2	47.3	13.70	.57	5.08	69.47	1.23	9.95	6,950	12,510
				C		37.9	48.2	13.95	.58	4.97	70.71	1.25	8.54	7,070	12,730
				D		44.0	56.0		.67	5.78	82.17	1.45	9.93	8,220	14,790
Yankee mine (highest bed—the Kellog)	600	17746	1.6	A	5.7	37.4	44.6	12.28	1.09	5.47	66.31	1.40	13.45	6,655	11,980
				B	4.1	38.0	45.4	12.48	1.11	5.38	67.41	1.42	12.20	6,765	12,180
				C		39.6	47.4	13.02	1.16	5.13	70.33	1.48	8.88	7,055	12,700
				D		45.6	54.4		1.33	5.90	80.86	1.70	10.21	8,115	14,600

Analyses of samples of coal from the Raton coal field—Continued.

Coal beds in Raton formation—Continued.

Name of mine.	No. on map (Pl. I.).	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heating value.	
					Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Reynolds mine (abandoned)	599	6244	3.4	A	5.6	33.8	49.3	11.29	.63	4.97	64.93	1.21	16.97	6,620	11,920
				B	2.3	35.0	51.0	11.69	.65	4.75	67.22	1.25	14.44	6,855	12,340
				C		35.8	52.2	11.96	.67	4.60	68.81	1.28	12.68	7,015	12,630
				D		40.7	59.3		.76	5.22	78.16	1.45	14.41	7,970	14,350
Llewellyn mine	576	6255	3.5	A	9.0	34.9	48.9	7.18	.54	5.34	67.48	1.22	18.24	6,815	12,260
				B	5.7	36.2	50.7	7.44	.56	5.13	69.93	1.26	15.68	7,060	12,710
				C		38.4	53.7	7.89	.59	4.77	74.19	1.34	11.22	7,490	13,480
				D		41.6	58.4		.64	5.18	80.55	1.45	12.18	8,135	14,640
Latimore mine (abandoned)	578	6287	2.9	A	6.7	33.0	52.5	7.83	.48	5.26	68.94	1.20	16.29	6,930	12,470
				B	3.9	33.9	54.1	8.06	.49	5.09	71.00	1.24	14.12	7,140	12,850
				C		35.3	56.3	8.40	.51	4.84	73.92	1.29	11.04	7,430	13,380
				D		38.6	61.4		.56	5.28	80.70	1.41	12.05	8,115	14,610

14796. This sample was collected at locality 103, in the ninth west entry of the Koehler mine, 4,900 feet southwest of the mine mouth, on September 27, 1912, by Willis T. Lee. It represents the lower bench of coal, 6 feet 3 inches thick, which at this point is overlain by bony coal 2 feet thick. For description of the bed see page 34.

12336. This sample was collected near locality 101, at the face of eighth west entry of the Koehler mine, 4,300 feet southeast of the mine mouth, on May 28, 1911, by J. C. Roberts. It represents a bench of coal 6 feet 2 inches thick, which at this point is overlain by bony coal 2 feet thick and underlain by an unmeasured bench of poor coal. For description of the bed see page 34.

12335. This sample was collected in room 20, off seventh east entry, 4,500 feet southeast of the mouth of the Koehler mine, on May 28, 1911, by J. C. Roberts. It represents the lower bench of coal 6 feet thick, which at this point is overlain by bony coal 2 feet thick and underlain by a bench of bony coal 1 foot thick. For description of the bed see page 34.

12337. This sample was collected in room 20, off seventh east entry of the Koehler mine, 4,200 feet southeast of the mouth, on May 28, 1911, by J. C. Roberts. It represents the coal bed with a thickness of 5 feet 9 inches. For description of the bed see page 34.

12338. This sample is a composite of samples Nos. 12335, 12336, and 12337.

17781. This sample was collected at locality 137, in room 71, off second east entry of the Koehler mine, on September 25, 1913, by Willis T. Lee. It was cut where the coal bed is very much broken by partings. (See No. 137, Pl. IV.) It represents the six benches of coal 10, 6, 17, 13, 9, and 38 inches thick and also the uppermost bench of bony coal 4 inches thick. For description of the bed see page 34.

33017. This sample was collected at the face of the main entry of the Koehler mine, on September 9, 1919, by Willis T. Lee. It represents the four lowermost benches of coal 21, 6, 12, and 20 inches in thickness. For section of the bed see page 34.

33018. This sample was collected at locality 129 on September 10, 1919, by Willis T. Lee. It represents all the coal in the bed at this locality in the Koehler mines, consisting of an upper bench 10 inches thick and a lower bench 5 feet 4 inches thick, which are separated by a layer of bone 1 foot 4 inches thick. For description of the bed see page 34.

6930. This sample was collected in room 5, off left entry No. 3 of the Willow mine at Van Houten, 800 feet south of the mine mouth, on December 6, 1908, by K. M. Way. It represents all the coal in the bed, consisting of four benches 39¾, 16, 15½, and 28 inches thick. For description of the bed see page 48.

3221. This sample was collected in the Willow mine in room 36, off right entry 4, 2,000 feet from mine mouth, by J. S. Burrows, on May 8, 1906. It represents benches of coal 11, 17, 30, and 10 inches thick, including a parting of shale one-fourth inch thick. For description of the bed see page 48.

3222. This sample was collected in the left entry of the Willow mine, 3,000 feet from the mine mouth, by J. S. Burrows, on May 8, 1906. It represents all the bed, 6 feet 11¾ inches thick, except three benches of bone, 7, 2, and 2½ inches thick. For description of the bed see page 48.

32592. This sample was cut in room 12, off No. 3 right entry of the Willow mine, on August 6, 1919, by J. J. Forbes.

32593. This sample was cut at the face of No. 2 south entry of the Willow mine, on August 7, 1919, by J. J. Forbes.

6417, 6418. These samples were taken in the main entry of the Willow mine No. 5, at locality 179, by Willis T. Lee, on August 25, 1908. Sample 6417 represents the three upper benches, 15, 6, and 40 inches thick, and sample 6418 the two lower benches, 1½ and 53 inches thick. For description of the bed see page 48.

6931. This sample was obtained in the crosscut between entries 3 and 4, near room 6 of Willow mine No. 5, 500 feet west of mine mouth, by K. M. Way, on December 6,

1908. It represents all the coal in the bed, comprising five benches 46, 5, 9, 19¼, and 28 inches thick. For description of the bed see page 48.

3226. This sample was obtained at locality 282 in room 6, off north entry 5 of the "New" Dutchman mine near Blossburg, north of slope, by J. S. Burrows on May 10, 1906. It represents all the bed except a parting of shale half an inch thick and a parting of bony coal 1½ inches thick. For description of the bed see page 113.

3227. This sample was obtained at locality 278, in room 1, off sub-entry 2, of the "New" Dutchman mine, southwest of the slope, by J. S. Burrows, on May 10, 1906. It represents all the bed except three partings 1, ½, and ¾ inch thick. For description of the bed see page 113.

14795. This sample was obtained at locality 283, in room 6, off first west entry, 400 feet from mouth of the new Gardiner mine near Blossburg, by Willis T. Lee, on September 27, 1912. It represents a bench of coal 5 feet 5 inches thick above which is a bench of bone 6 inches thick. For description of the bed see page 117 and No. 283, Plate XI.

18166, 18169, 18171, 18174, 18175. These samples were collected in the Dawson mine, on November 6, 1913, by C. S. Stevenson and A. W. Strane. Sample 18166 was cut at the face of No. 16 east entry, off Nos. 1 and 2 north entries. Sample 18169 was cut in room 35, off No. 12 west entry, off Nos. 1 and 2 north entries. Sample 18171 was cut in fifth room from No. 1 south entry, off No. 4 entry, off "Hi" line. Sample 18174 was cut at face of No. 13 east entry, off "Hi" line. Sample 18175 was cut at face of No. 1 east entry, off No. 1 south entry, off No. 9 west entry, off Nos. 1 and 2 north entries.

Sections of coal beds at points in Dawson mine where samples were taken.

	Sample 18166.		Sample. 18169.		Sample. 18171.		Sample. 18174.		Sample. 18175.	
	Ft.	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
Coal (sampled)	1	11		5	1	6	......	......	......	......
"Sulphur" band		½		½		1½	......	......	......	......
Coal (sampled)	1	4½	1		1			7		4½
Parting		½		½		1		1		3½
Coal (sampled)	2	4	3	10	3	3	6	3	4	2
	5	8½	5	4	5	11½	6	11	4	10

256–D. This sample was cut in room 21, off No. 7 east entry, off No. 1 north entry of the Dawson mine, on January 15, 1908, by J. W. Groves. The section of the coal bed at this point is as follows:

Section of coal bed at point in Dawson mine where sample 256–D was taken.

	Ft.	in.
Coal (sampled)		5
Shale		3
Coal (sampled)	1	4
Shale		1
Coal (sampled)	3	
Shale		1
Coal (sampled)		7
	5	9

6606. This sample was cut in the Dawson mine on January 15, 1908, by J. W. Groves, but there is no record of the particular place in the mine at which the sample was obtained and of the section of the coal bed. The total thickness of the bed at the point sampled is 9 feet 8 inches.

12235. This sample is a composite of two mine samples, 12233 and 12234, cut in the Dawson mine by J. C. Roberts on May 17, 1911.

33020. This sample was cut in the air shaft of the Dawson mine, at locality 306, on October 21, 1919, by Willis T. Lee. The sample represents the lower bench of coal, 2 feet 9 inches thick, which lies above the main coal of the mine. For description of the bed see page 134.

33021. This sample was cut in the Dawson mine, at locality 316, at the face of the main entry, on October 21, 1919, by Willis T. Lee. The sample represents the entire bed, which here consists of a single bench of coal 5 feet 4 inches thick. For description of the bed see page 134.

33019. This sample was cut in the Dawson mine at the face of the main entry on October 21, 1919, by Willis T. Lee. The sample represents the upper bench of coal 6 feet thick. For description of the bed see page 134.

33022. This sample was cut at the face of the main entry of the Dawson mine, at locality 322, on September 15, 1919, by Willis T. Lee. It represents the lower bench of coal 6 feet 4 inches thick of a bed 9 feet 1¼ inches thick. For description of the bed see page 134.

6286. This sample was cut at a point in the old Wagon mine 1,800 feet from the mine mouth, at locality 339, on July 23, 1908, by Willis T. Lee at the time this mine was in active operation. It represents the lower bench of coal 4 feet 7½ inches thick of a bed 6 feet 2 inches thick.

14791. This sample was cut at locality 343, in the Sugarite mine 1,500 feet southwest of the mine mouth, on September 25, 1912, by Willis T. Lee. It represents the lower bench of coal, 5 feet 1 inch thick, of the bed that is 5 feet 6½ inches thick. For description of the bed see page 153.

14792. This sample was cut at locality 355, a point in the Sugarite mine 1,200 feet northeast of the mine mouth on September 25, 1912, by Willis T. Lee. It represents the lower two benches of coal, 3 feet 5 inches and 1 foot 4 inches thick, of the bed which measures 5 feet 7 inches in thickness. For description of the bed see page 153.

6284. This sample was cut at a fresh face exposed in a gulch, on July 15, 1908, by Willis T. Lee. It represents 4 feet 1 inch of coal. For description of the bed and condition of exposure see page 153.

6285. This sample was cut 50 feet from mouth of abandoned entry of the old Hartsel mine, at locality 364, on July 21, 1908, by Willis T. Lee. It represents the lower two benches of coal 9 inches and 2 feet 10 inches thick of the bed which here measures 4 feet to 8½ feet in thickness. For description of the bed see page 153.

17703, 3228, 3229. These samples were cut in the Brilliant mine on May 9, 1906, and August 30, 1913, by J. S. Burrows and Willis T. Lee. The sections of the coal bed at the points sampled are shown in the table on page 250. For description of the bed see page 194.

Sections of coal bed in Brilliant mine at points where samples were taken.

	Sample 17703.	Sample 3228.	Sample 3229.
	Ft. in.	*Ft. in.*	*Ft. in.*
Coal (sampled)	6	....	....
Shale	2	....	....
Coal (sampled)	9	9	....
Shale	8	....	....
Bone	....	1 4	....
Coal (sampled)	1 9	1 6	1 10
Shale	½	....	....
Sandstone	....	¾	2½
Coal (sampled)	1 2	2	2 2
Shale	2	....	....
Coal (sampled)	8	....	....
	5 10½	5 7¾	4 2½

257–D, 258–D. These samples were cut in the Red Robin mine, at Wootton, Colo. on January 25, 1908, by J. W. Groves. The sections of the coal bed at the point sampled are as follows:

Sections of coal bed in Red Robin mine at points where samples were taken.

	Sample 257–D.	Sample 258–D.
	Ft. in.	*Ft. in.*
Coal (sampled	1	1
Shale	1	1¼
Coal (sampled)	1 10	2 10
Bone	2	....
Shale	....	1
Coal (sampled)	1 3	7
Shale	1	1½
Coal (sampled)	4½	5
	4 9½	5 1¾

6243. This sample was cut in the main entry of the Yankee mine 1,000 feet from the mine mouth on July 2, 1908, by Willis T. Lee. It represents all the coal in benches 10, 6½, 2½, 6½, and 25 inches thick. Total thickness of bed 5 feet 7 inches.

13365, 13366, 17746. These samples were cut in the mine on February 8, 1912, and September 18, 1913, by J. C. Roberts and Willis T. Lee. The sections are as follows:

Sections of coal bed in Yankee mine No. 3 at points where samples were taken.

	Sample 13365.	Sample 13366.	Sample 17746.
	Ft. in.	*Ft. in.*	*Ft. in.*
Coal	5	5	....
Shale	1½	4	....
Coal	1	1	7
Shale	1	1½	11
Coal	7	7	1 7
Shale	1	1 3	1 1
Coal	2 7	2 7	1 9
	5 9½	6 3½	5 11

6244. This sample was cut in the Reynolds mine at locality 594, on July 2, 1908, by Willis T. Lee. It represents the lower three benches of coal, 9, 19½, and 22 inches thick. The entire bed is 6 feet 5 inches thick. For description of the bed see page 227.

6255. This sample was cut in the main entry of the Llewellyn mine, locality 576, on Johnson Mesa, 150 feet from the mine mouth, on July 8, 1908, by Willis T. Lee. It represents the five benches of coal, 6, 12, 39, 5, and 15½ inches thick. Total thickness of bed 7 feet 3½ inches. For description of the bed see page 220.

6287. This sample was cut in the main entry of the abandoned Latimore mine, at locality 578, on Johnson Mesa, 300 feet from mine mouth, on July 23, 1908, by Willis T. Lee. It represents the five benches of coal, 13, 6½, 4, 13, and 22 inches thick. For description of coal bed see page 222.

QUANTITY OF COAL MINED.

Although coal has been mined on a commercial scale since the early seventies, no records are available for the production before 1882. As records are tabulated by counties, the following figures for Colfax County, which have been taken from Mineral Resources of the United States for the years stated, indicate the production of the entire Raton field, all the producing mines of which are described in this bulletin.

Coal mined and coked in the Raton field.

Year.	Total amount produced (short tons).	Value.	Amount coked (short tons).
1882	91,798		
1883	112,089		
1884	102,513		
1885	135,833		
1886	87,708		
1887	154,875		
1888	227,427		
1889	151,464	$201,027	
1890	151,400	198,500	
1891	295,089	399,432	
1892	297,911	393,426	
1893	249,783	301,503	
1894	114,985	143,925	
1895	187,102	224,218	
1896	179,415	223,101	
1897	163,463	195,443	
1898	269,215	320,443	17,124
1899	368,373	439,984	
1900	388,480	433,146	27,333
1901	249,296	262,225	14,295
1902	346,373	392,244	22,519
1903	723,786	874,837	62,713
1904	788,955	931,003	103,311
1905	1,031,829	1,232,412	161,711
1906	1,292,241	1,576,636	289,107
1907	1,844,550	2,373,502	498,279
1908	1,781,635	2,052,322	450,114
1909	2,013,318	2,196,468	741,759
1910	2,651,585	3,310,412	701,204
1911	2,297,611	3,066,686	767,108
1912	2,691,306	3,514,360	839,264
1913	2,749,765	3,652,245	938,432
1914	3,015,363	4,627,978	742,835
1915	2,866,442	3,842,048	734,713
1916	2,837,613	3,809,205	844,083
1917	3,114,604	5,289,414	991,488
1918	3,029,221	7,249,234	1,108,092
1919	2,171,531	6,018,283	473,033
1920	2,556,919	8,493,000	453,944
1921	1,714,851	6,077,000	30,435
1922			

INDEX.


EXPLANATION
SEDIMENTARY ROCKS
Qhg
High-level gravels
(sand, gravel, and boulders)
QUATERNARY
Eocene
Raton formation
(sandstone, brown to buff shale, and coal beds; conglomerate at base)
TERTIARY
UNCONFORMITY
Kv
Vermejo formation
(dark shale, light-colored friable sandstone, and Raton coal beds)
Ktd
Trinidad sandstone
(massive light-gray feldspathic sandstone)
Kp
Pierre shale
(drab to black fossiliferous shale; containing limestone concretions in upper part; in southeast parts of Raton and Koehler quadrangles includes representatives of Niobrara limestone and Benton shale, of underlying Colorado group, not readily separable from Pierre shale)
Upper Cretaceous
Montana group
CRETACEOUS
IGNEOUS ROCKS
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Dikes and sheets, chiefly basalt; some andesite and lamprophyre
(Ruled pattern indicates dike rock that replaces coal bed in mine)
QUATERNARY
ECONOMIC DATA
Coal bed outcrops
(Raton coal beds r, in Vermejo formation. Sugarite, sg, Yankee yk, Savage Canyon, sc, Tin pan, tp, Potato Canyon, pc, and other coal beds in Raton formation. Coal altered to coke or graphite where in contact with igneous rocks)
Coal mine entries
Coal prospects and location of measured surface sections
Diamond drill tests for coal
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Mine workings in 1915
Economic note: Bituminous coking coal is extensively mined in the Vermejo and Raton formations.
Land lines on map are based on found corners indicated thus (+)
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1920
DIAGRAM OF QUADRANGLES
BRILLIANT
RATON
KOEHLER
Geology by Willis T. Lee.
Surveyed in 1913 and 1919.
GEOLOGIC MAP AND SECTIONS
OF THE
RATON COAL FIELD
COLFAX COUNTY, N. MEX.
SHOWING OUTCROPS OF COAL BEDS
Scale 1/62500
4 Miles
5 Kilometers
Contour interval 50 feet.
Datum is mean sea level.
1923
M A X W E L L
G R A N T
RATON
BARTLETT MESA
JOHNSON MESA
Black Mesa
Round Mesa
Meloche Mesa
Towndrow Peak
LAS ANIMAS CO.
COLFAX CO.
COLORADO
NEW MEXICO
Base from U. S. Geological Survey topographic maps of Brilliant, Raton, and Koehler quadrangles.
ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY
SECTION ALONG LINE A-A'
SECTION ALONG LINE B-B'